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UNITED STATES DEPARTMENT OF AGRICULTURE

Handling and Shipping Early Potatoes[1]

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CONTENTS

EVALUATION OF HANDLING AND SHIPPING PRACTICES

Early potatoes are highly perishable and should be handled accordingly. Rough handling that results in cuts, skinning, and bruises should be avoided at all times, because such injuries may lead to decay. Walking on top of the load on a truck or in a railroad car is bad practice. It should be avoided as much as possible.

[1] This circular summarizes both published and unpublished results of studies made during the past 6 years by W. R. Barger, C. O. Bratley, L. H. Evans, J. M. Lutz, L. P. McColloch, W. T. Pentzer, G. B. Ramsey, H. A. Schomer, E. V. Shear, M. A. Smith, J. S. Wiant, J. R. Winston, R. C. Wright, and the author, under the leadership of D. F. Fisher, principal horticulturist in charge of investigations on the handling, transportation, and storage of fruits and vegetables. It also contains brief references to earlier work by investigators in this Bureau and some discussion of investigations made by agencies outside the U. S. Department of Agriculture. Credit for work done on the various phases of the subject is shown by appropriate footnote references.

Potatoes should be picked up within 15 to 30 minutes after being dug, in order to avoid drying, browning, and heat injury. This is especially important when the air temperature is above about 90° F. or the day is dry or windy. Under such severe conditions even a 15-minute exposure may cause some damage. If the average temperature of potatoes in transit is above 70°, potatoes injured by heat in the field are likely to be attacked by bacterial soft rot and those damaged by drying and browning prior to loading are likely to show stickiness and decay by the time they reach the market.

Potatoes in bags or other containers should be hauled from the field as soon as possible. It is not safe to leave the filled containers in the field on a hot and dry or windy day for longer than about half an hour. While on the way to the packing house the load should be covered with a tarpaulin whenever practicable, in order to prevent drying, browning, and heat injury.

In the South and East it is good practice to dig and bag potatoes in late afternoon and leave them in the field overnight to cool, but they should be hauled to the packing house before the air temperature rises the next day. In arid and semiarid regions of the West digging early in the morning is more desirable, because the humidity is usually highest then and there is less danger of drying by wind.

The best methods of stowing bags, baskets, or crates in a car are those that keep shifting in transit to a minimum. For bags on long hauls two of these are the 5–3–2–3 pyramid load and the pyramid through load. For short hauls, where shifting of the load in transit is less likely to occur, various types of aisle load can safely be used. It is always desirable, however, to see that the load is well tied together in order to keep shifting in transit to a minimum.

The kind of service to be used for the protection of shipments of early potatoes in transit will depend on the length of haul, the weather at digging time, and that anticipated during shipment.

Potatoes harvested in the South in cool or moderately warm weather and likely to pass through cool weather on the way to market are benefited very little, if at all, by refrigeration in transit. For such shipments standard ventilation is satisfactory.

When refrigeration is needed for shipments from the South, initial icing with only a ton or two of ice per car is sometimes sufficient. Placing the ice in the upper half of the bunker will give better results than placing it in the lower half. It is frequently desirable to open the vents when cars reach the northern part of their journey in order to take advantage of the cooler outside air.

For transit periods of 2 or 3 days, icing of the cars can safely be delayed 24 to 36 hours after loading, provided the potatoes were dug and loaded in cool to moderately warm weather.

For long hauls in hot weather full-bunker initial icing with one re-icing in transit is recommended.

Pre-icing the cars just before they are loaded is preferable to icing after loading.

Precooling alone does not give as good transit temperatures as initial icing with one re-icing in transit and does not control

decay as well. Precooling with one re-icing in transit has given good results in some instances, but the method is rather expensive.

After precooling, the average temperature of the load cannot be estimated accurately unless potato temperatures are taken at several places in the load, preferably at the top and bottom doorway, top quarter length, and top bunker and if possible at the bottom quarter length.

Precooling that will give an average load temperature of 60° F. is desirable, but such precooling cannot be done in a hurry. Operation of precoolers for 4 or 5 hours is much better than for 2 or 3 hours.

The use of fan cars and initial icing gave the best and most evenly distributed transit temperatures obtained by any of the refrigeration methods tested.

Mesh or net bags are not recommended, because they produce bag marks on the potatoes.

In most respects bags, crates, and baskets are equally satisfactory for use in transit. In bags some skinning probably occurs, because of slight movement of the potatoes due to shifting of the load. When potatoes are shipped in crates the small ones sometimes fall out between the slats, because of either shifting of the load or breakage.

On long hauls it is desirable to have floor pads under the bottom-layer bags to prevent floor bruising.

Early potatoes, which are dug before they mature, are usually marketed directly from the field. They are sometimes referred to as new potatoes. Unlike the late crop, they are stored only occasionally and then only for very short periods. They constitute the bulk of the shipments from the South and also an important part of those from California, Colorado, Kansas, Missouri, Nebraska, New Jersey, and several other States. Carlot shipments of early potatoes from 23 States for 1944 are shown in table 1. The tabu-

TABLE 1.—*Carload shipments of early potatoes from 23 States, by months, 1944*[1]

State	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Alabama	0	0	0	96	2,343	120	27	0	0	0	0	0	2,586
Arkansas	0	0	0	0	0	503	90	0	0	0	0	0	593
California	0	0	2	435	7,051	16,425	3,329	2,037	0	0	0	0	29,279
Colorado	0	0	0	0	0	34	297	2,662	0	0	0	0	2,993
Florida	414	680	478	2,187	1,327	53	7	1	0	0	0	193	5,340
Georgia	0	0	0	0	43	18	0	0	0	0	0	0	61
Idaho	0	0	0	0	0	0	640	1,689	0	0	0	0	2,329
Kansas	0	0	0	0	0	0	369	69	0	0	0	0	438
Kentucky	0	0	0	0	0	0	18	3	0	0	0	0	21
Louisiana	0	0	0	69	1,927	1,114	18	0	0	0	0	1	3,129
Maryland	0	0	0	0	2	0	675	76	0	0	0	0	753
Mississippi	0	0	0	0	431	372	0	0	0	0	0	0	803
Missouri	0	0	0	0	515	39	0	0	0	0	0	0	554
Nebraska	0	0	0	0	0	0	222	1,157	0	0	0	0	1,379
New Jersey	0	0	0	0	0	0	565	4,210	0	0	0	0	4,775
North Carolina	0	0	10	18	24	3,323	1,227	1	1	0	1	0	4,605
Oklahoma	0	0	0	0	0	227	12	0	0	0	0	0	239
Oregon	0	0	0	0	0	654	1,214	0	0	0	0	0	1,868
South Carolina	1	1	0	0	198	623	1	0	0	0	0	0	824
Tennessee	0	0	0	0	0	232	159	2	23	0	0	0	416
Texas	17	0	245	1,030	37	448	246	784	146	4	0	4	2,961
Virginia	0	0	0	3	4	1,618	2,996	19	0	0	0	0	4,640
Washington	0	0	0	0	0	0	1,392	760	0	0	0	0	2,152
Total	432	681	735	3,838	13,902	25,803	13,504	13,470	170	4	1	198	72,738

[1] From data compiled by the Office of Food Distribution, War Food Administration.

lation is for January to August, inclusive, except for Florida, Louisiana, North Carolina, Tennessee, and Texas from which a few shipments were made in September, October, November, and December. The total, 72,738 carloads, is approximately 26 percent of the total potato shipments, 275,581 carloads, of the United States for that year. These figures show that the early-potato crop is an important part of the food supply of the American people. Its importance lies, of course, not only in its size but also in the fact that most of it comes on the market at a time when the old crop of the year before is gradually being used up and becoming less attractive to consumers than it was earlier.

The susceptibility of early potatoes to skinning, browning, and decay—decay following both browning and heat injury—is a serious handicap to the successful marketing of this crop. It is no exaggeration to say that early potatoes are highly perishable, probably as much so as bunch carrots or new cabbage, for example, and that they need much more careful treatment during harvesting and marketing than they commonly receive. The failure of growers, shippers, and transportation agencies to appreciate this fact results in losses that could be largely avoided by closer attention to a few important matters.

INJURIES FROM MISHANDLING IN FIELD AND PACKING HOUSE

Effects of Skinning

Being for the most part immature, early potatoes skin easily and are more susceptible to damage from bruising than more mature ones. Skinning may occur during digging or in any subsequent handling operations. During digging, skinning is more likely to be serious if the soil is wet than if it is moderately dry. The skin slips more easily on freshly dug wet potatoes than on dry ones. However, growers often prefer to dig potatoes grown under irrigation before the soil dries out, because it packs when wet and clings to the potatoes when it dries. Then when removed it takes the skin with it.

Skinning is also caused by rough handling in picking up potatoes after they are dug and in loading bags or other containers onto trucks for hauling from the field. In the packing house considerable additional skinning may be caused when the potatoes are emptied onto the conveyor belt that leads up to the washer and while they are being subjected to the washing process. It has been observed that new potatoes as they come from the washer have sometimes lost so much skin that on casual examination they appear to have none left. Skinning, particularly in bags, may occur during loading and the later handling of the bags at the market. It is occasionally so extensive that a handful or more of loose fragments of skin comes out with the potatoes when a bag is emptied into a grocer's bin. If potatoes lose most of their skin, as sometimes happens during digging and washing operations

early in the season, they start to market very poorly protected against the hazards of transportation.[2]

It is doubtful whether many persons concerned with the practical aspects of growing, harvesting, and marketing potatoes realize how important the skin of the tuber is as a protection against injury. The skin (periderm) consists of several layers of cells, sometimes a dozen or more, whose walls are infiltrated with suberin, the substance that occurs in all corky tissues in plants. The skin is therefore a corky covering over the potato.

FIGURE 1.—"Feathering," or peeling, of the outer skin on a new Triumph potato.

"FEATHERING"

"Feathering" is a less serious type of skinning in which fragments of the loosened skin remain attached to the potato and stick up from its surface (fig. 1). It is occasionally so conspicuous as to detract from the appearance of the potatoes and affect their market price.

LOSS OF WEIGHT

Because of the suberin it contains the skin of a potato is practically impervious to moisture and air except at the lenticels, where the protective layer is a little thinner and less fully suberized than in the intervening areas. A potato from which all of the skin has been removed may lose a tenth or more of its weight in 24 hours when held in a dry place at room temperature; an unskinned potato loses only a fraction of 1 percent of its weight in the same time under the same conditions.

In a test conducted in New York City[3] six 10-pound lots of Triumph potatoes from Florida were held for 15 days in a room where the temperature ranged from 52° to 66° F. and the relative humidity averaged about 45 percent. Two of the lots consisted of sound, unskinned potatoes, two of skinned ones, and two of bruised and cracked ones. At the end of the holding period it was found that the sound potatoes had lost less than 1 percent in

[2] WRIGHT, R. C., LUTZ, J. M., and BRATLEY, C. O. INVESTIGATIONS ON THE HANDLING AND TRANSPORTATION OF EARLY POTATOES IN THE EAST. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Div. Fruit and Veg. Crops and Dis. H. T. & S. Office Rpt. 93, 21 pp. 1943. [Processed.]

[3] E. V. SHEAR. Unpublished data on loss of weight in potatoes after shipment. 1944.

weight, whereas the skinned and the bruised and cracked lots had lost from 3 to 3½ percent. Furthermore, all injured lots had shriveled at the injured places and were definitely unattractive if not unmarketable.

Skinned spots often dry out and sink below the level of the surrounding unskinned area. This is particularly noticeable when the skinned spots are small. These small sunken spots are sometimes called pits. They result merely from the loss of water from exposed potato flesh and not from bruising, as is so often thought.

BROWNING

FIELD AND LABORATORY TESTS

The most serious results of skinning are the browning of skinned spots and the stickiness and decay that often develop on the browned areas. Browning is most likely to occur on potatoes skinned in digging and allowed to lie on the ground for some time before being picked up or on those left in the field in unprotected bags for several hours before being hauled to the packing shed or freight car. It is most pronounced when skinned potatoes are exposed to drying winds, even in bags in the field, but it may also occur when they are hauled from the field in open trucks without protection from the wind or during shipment to market in ventilated cars. In districts where drying winds are frequent, the use of closely woven picking bags will help greatly in reducing browning (*8*).[4]

The degree to which browning is present has been made a grade specification that must be applied in Federal-State shipping point inspections and in Federal inspections on the market. Browning is sometimes so severe and extensive that a carload is thrown out of grade because of it.

TABLE 2.—*Effect of method and length of exposure on browning of Irish Cobbler potatoes, Gilcrest, Colo., dug August 11, 1942, and inspected August 14*

Exposure		Potatoes browning on skinned areas when dug at indicated time			
Method	Duration	6:15 a. m.	10 a. m.	1:15 p. m.	4 p. m.
	Minutes	*Percent*	*Percent*	*Percent*	*Percent*
Potatoes picked up immediately	0	0	0	0	0
Potatoes spread out	15		0	0	2.5
	30		1.9	3.2	13.3
	60		14.6	83.2	96.6
	(1)	23.7			
Potatoes in bags (potato burlap)	60		8.7	5.8	4.2
	120		5.3	21.4	34.8
	240		17.0	46.3	[2] 16.1
	(1)	16.2			

[1] All day and overnight. [2] Left in field overnight.

In a few localities the term "scald spot" is in use as a name for skinned areas severely injured by drying winds and subsequent browning; it will not be used in this sense in this circular because of possible confusion between the condition it is meant to describe and another injury also referred to frequently as "scald" but more properly termed "heat injury" which is manifest when bacterial soft rot follows as a secondary development. The term "browning"

[4] Italic numbers in parentheses refer to Literature Cited, p. 44.

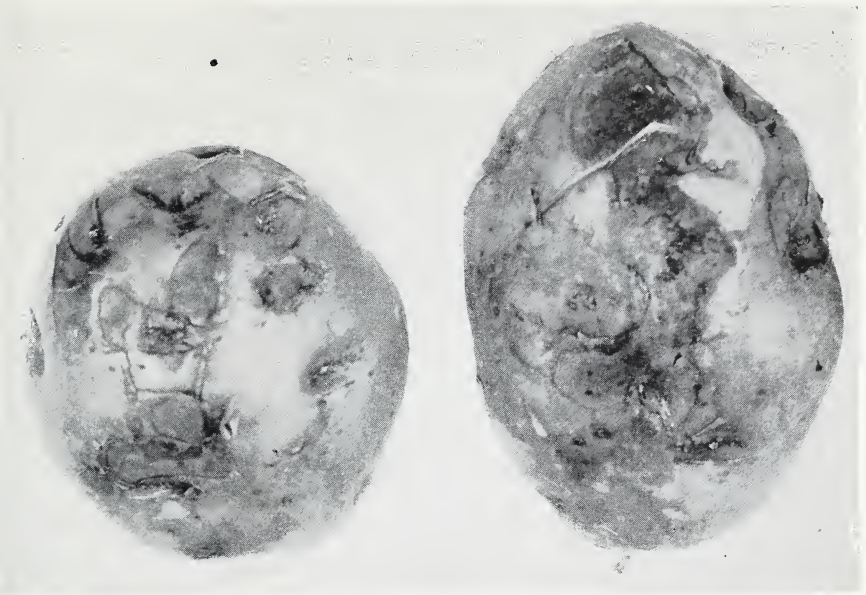

FIGURE 2.—Red Warba potatoes dug after 7 p. m. showing spots caused by drying and browning as a result of being left in a burlap bag overnight in a field in Nebraska on July 24. Air temperature, 90° to 95° F. at time of digging and dropping to 76° during night; relative humidity, 40 to 56 percent; wind, considerable. About 50 percent of the tubers were affected.

will be used for the scald spot type of injury, which may be slight or severe and may or may not be accompanied by drying out and sinking of the skin and flesh at affected spots (fig. 2).

As shown by various investigators (*1*, *4*) [5] [6] browning can develop on skinned potatoes after 15 to 30 minutes' exposure to conditions that favor its development. The affected spots darken as time goes on, however, and become much more noticeable after 2 or 3 days than at the end of the exposure. Eventually they may turn almost black; in a moist atmosphere they become sticky with bacterial growth that finally results in decay (p. 9). The results of a test on the effects of field conditions in Colorado on the development of browning are summarized in table 2.[7]

Tests were made near Hastings, Fla., in 1942;[5] in these, newly dug and moderately skinned potatoes of the Katahdin and Sebago varieties were spread out over freshly dug soil at 3 p. m. on a warm, bright day with a fairly high relative humidity. Lots of about 50 tubers each were picked up immediately and after 15, 30, 60, and 120 minutes' exposure, were put into burlap bags, and were stored in a closed shed. During exposure the air (shade) temperature ranged between 84° and 86° F. and the relative humidity was about 62 percent. The wind velocity was 2 to 3 miles an hour.

[5] See footnote 2, p. 5.

[6] J. M. LUTZ. Unpublished report on browning of skinned potatoes when exposed to various conditions in the field. 1941.

[7] RAMSEY, G. B., LUTZ, J. M., and EDGAR, A. D. EXPERIMENTS ON SHIPPING WASHED POTATOES FROM CENTRAL NEBRASKA AND GILCREST, COLORADO DURING JULY AND AUGUST, 1942. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Div. Fruit and Veg. Crops and Dis. H. T. & S. Office Rpt. 103, 26 pp., illus. [1943.] [Processed.]

The temperature of the potatoes when dug was 85° to 86°; after 30 minutes' exposure it was 88° to 94° just below the exposed surface; after 60 minutes it was 88° to 96°, or about 4° to 10° hotter than the air.

The Sebago potatoes showed no browning at the end of any of the exposure periods, but the Katahdin began to show it after they had been exposed 120 minutes. Under other conditions this variety showed browning when exposed for 30 minutes. Inspection of all lots after 1 and 4 days showed that the longer the exposure in the field the greater was the percentage of browned potatoes. In the Katahdin lot exposed for 15 minutes only 2 percent showed slight browning, whereas in that exposed for 120 minutes 85 percent were severely browned. At the end of the 4-day holding period the browned spots were darker than after 1 day and many of them had become sticky with bacterial growth. Similar results were obtained with Triumph and White Rose potatoes in Alabama and with Irish Cobbler in North Carolina and Maryland.

These various tests and similar ones made in other parts of the country showed that potatoes dug in the middle of the day or early in the afternoon and left exposed on the ground are much more likely to be damaged by browning and heat injury (p. 15) than those dug early in the forenoon or late in the afternoon. In the humid South and East it is good practice to dig and bag potatoes late in the afternoon (preferably after about 4 o'clock) and leave them in the field overnight to cool. However, when this is done the potatoes should be hauled from the field early the next morning before they have a chance to warm up. The overnight stay in the field not only cools the potatoes but, because of the higher relative humidity at night, also favors the suberization, or healing, of skinned areas. The practice is not desirable in the western arid or semiarid regions, where humidity is likely to be low at night as well as in the daytime, because the low humidity delays healing and may cause an increase in browning. In dry regions digging early in the morning has been found desirable, because the humidity is usually higher then than at any other time of the day or night and there is less likelihood of injury by drying winds (*8*). The effect of leaving potatoes in the field in bags in central Nebraska is shown in figure 2.

In some parts of the South there are occasionally high winds accompanied by low humidity for a day or two during potato harvest. Under these conditions freshly dug, immature potatoes brown quickly and severely at skinned places and show pronounced blackening and stickiness by the time they reach market. Undoubtedly the best procedure at such times would be for growers to stop digging until weather conditions become normal again. If this seems impracticable, growers could prevent some of the damage by digging early in the morning or late in the afternoon when the winds are likely to be low.

Tests in California (*1*) brought out the fact, also noted during tests made in Nebraska in 1942,[8] that browning of skinned potatoes may occur on days that are not unusually hot and windy. The authors of a Nebraska report stated (*4*, *p. 13*): "On a day

[8] See footnote 7, p. 7.

that experienced growers considered very good potato-digging weather, tubers harvested at different times in the day were exposed in the field for various periods of time before picking and in sacks after picking. They were then stored in a cool shelter for two days before the extent of damage to tubers was determined . . ." They further reported that inspection at the end of that time showed very clearly the importance of prompt picking, for under the relatively mild field conditions much damage was done in as short a time as 15 minutes — especially in midday when the air was driest. They concluded (*4, p. 14*) that "it is a mistake to leave sacks of potatoes in the field or in exposed positions at the packing sheds on windy days for as much as one hour even if the temperature is not high."

FIGURE 3.—Skinned, immature potato exposed in a draft from an electric fan at a temperature of 50° F. and a relative humidity of 55 percent, then held (*A*) at 75° and 50 percent humidity for 3 days and (*B*) at 70° and 70 percent for 3 days more. Note bacterial growth on darkened, skinned area in *B*.

The results just discussed also emphasize the fact that air movement alone is not enough to cause browning of skinned potatoes. The air must be dry. In laboratory tests (*5*) it was found that if skinned potatoes are placed in the draft from an electric fan in air of high humidity (90 to 95 percent) they can be blown for 24 hours or longer without becoming browned and that high temperatures are not necessary for the occurrence of browning; it can be produced by exposing skinned potatoes to moving, fairly dry air at 40° to 50° F. (figs. 3 and 4). It has been observed in

FIGURE 4.—Skinned, immature potato exposed in a draft from an electric fan at 70° F. and a relative humidity of 70 percent and then held for 3 days at the same temperature and humidity. Note only slight browning and freedom from bacterial growth.

Idaho in dry, cool weather late in October. Investigators in California (*1*) found that skinned White Rose potatoes showed marked browning after being held for 10 days in an electric refrigerator at low humidity.

Bags are not a sure protection against the browning of potatoes in the field. Much depends on the kind of material of which they are made. Investigations were made on this problem in Alabama in 1942 [9] with immature White Rose and Triumph potatoes. The test lots were dug about 1:30 p. m.; some were spread out unprotected on the soil and others were placed in used fertilizer bags and in potato bags of the ordinary type. Both kinds were of burlap, but the fertilizer bags were heavier and more closely woven than the ordinary type and, therefore, afforded more protection from the wind. Exposure in the field was for 1, 2, and 4 hours. The air temperature when these potatoes were dug was 85° F. The test lots were inspected after being held 3 days in a closed implement shed. It was then found that browning had not been entirely prevented in the bags although it was much less there than on potatoes that had been spread on the ground. Browning was also somewhat less in the tightly woven fertilizer bags than in the ordinary potato bags.

In other tests in Alabama with the White Rose and Triumph varieties, it was found that 3 days after exposure in the field browning on tubers picked up promptly after digging was much less than on those that had been spread out on the ground. However, the browning of the bagged potatoes was still great enough to be of commercial importance. In field tests with Triumph potatoes in Colorado burlap bags did not provide much protection from browning (*4*). On the other hand it was found that covering truck loads of bagged potatoes with a tarpaulin while they are being hauled from field to packing house is beneficial in preventing browning of skinned spots (*1*, *4*, *8*) (fig. 5).

[9] See footnote 2, p. 5.

In California in 1943 (*8*) [10] tests were made to determine the effectiveness of different kinds of bags in preventing browning of White Rose potatoes. The test lots were dug about 2 p. m. when the air temperature was 90° F. and the relative humidity 19 percent. The crop was about 4 months from planting and the skin of the tubers was fairly well set, but considerable skinning occurred during harvest. The test lots were inspected after they had been held in bags in the field for 1½ hours and had been en route to the packing house or on the packing-house platform for another 3½ hours. It was found that browning had occurred on 33 percent of the potatoes in burlap potato bags and on 29.5 percent of those in burlap grain bags, but on only 6.3 percent of those in canvas bags and 1.5 percent of those in fertilizer bags having paper linings. The browning in burlap potato and burlap grain bags was decidedly of commercial importance, because all of the potatoes in them had to be thrown into a lower grade than those in canvas and paper-lined fertilizer bags. (See also p. 36.)

VARIETAL SUSCEPTIBILITY

Some varieties brown much more readily than others when skinned and exposed to dry air. Of the commoner commercial varieties those most susceptible under field conditions are White Rose, Katahdin, and Russet Burbank. Russet Burbank, however, is grown

FIGURE 5.—Load of bagged potatoes covered with a tarpaulin to prevent browning and heat injury.

[10] BARGER, W. R., and MORRIS, L. L. TIGHTER PICKING SACKS REDUCE SURFACE BROWNING OF EARLY WHITE ROSE POTATOES. Calif. Agr. Expt. Sta. Unnumbered Rpt. [3] pp. 1943. [Processed.]

very little for the early crop. Next in susceptibility are Irish Cobbler, Red Warba, Triumph, Pontiac, and Chippewa. Sebago browns least of all and partly for that reason is replacing Katahdin in some of the large producing areas of the South. Browning is usually more intense on Katahdin, White Rose, Irish Cobbler, and Triumph than on other varieties grown for the early crop.

Browning is usually most marked at the bud end of the potato, possibly because that end skins most easily. Tubers of the Russet Burbank variety brown so quickly on any part of the surface that if one of them is skinned from end to end by scraping a narrow strip with a knife, the exposed surface at one end may be perceptibly browned by the time the skinning operation has reached the other. Browning on the White Rose variety is also common and is often accompanied by marked wilting. Judging from the amount of browning often seen on White Rose potatoes on the market, it is probable that this variety browns about as seriously as the Russet Burbank. It is noteworthy, however, that shipments of White Rose potatoes often show damage from stickiness and decay that follow browning, whereas those of Russet Burbank rarely do. The difference undoubtedly results from the fact that the White Rose is harvested and marketed during warm or hot weather and the Russet Burbank during the cool weather of early fall.

Relation of Heat Injury and Bacterial Soft Rot

BACTERIAL SOFT ROT

A familiar sight in railroad receiving yards at large terminal markets is men at work inside a car loaded with potatoes and alongside the car a pile of rotten potatoes which they have thrown away (fig. 6). Such a sight may be seen at almost any season of the year, but it is most common during the months when early potatoes are being marketed. If growers and shippers of this crop could see and smell these evidences of waste and loss, they would realize more clearly than many of them do now the need for all possible care in the handling of the potatoes sent to market.

FIGURE 6.—Pile of waste potatoes, most of which are affected with bacterial soft rot, outside a car in which the load had to be reconditioned.

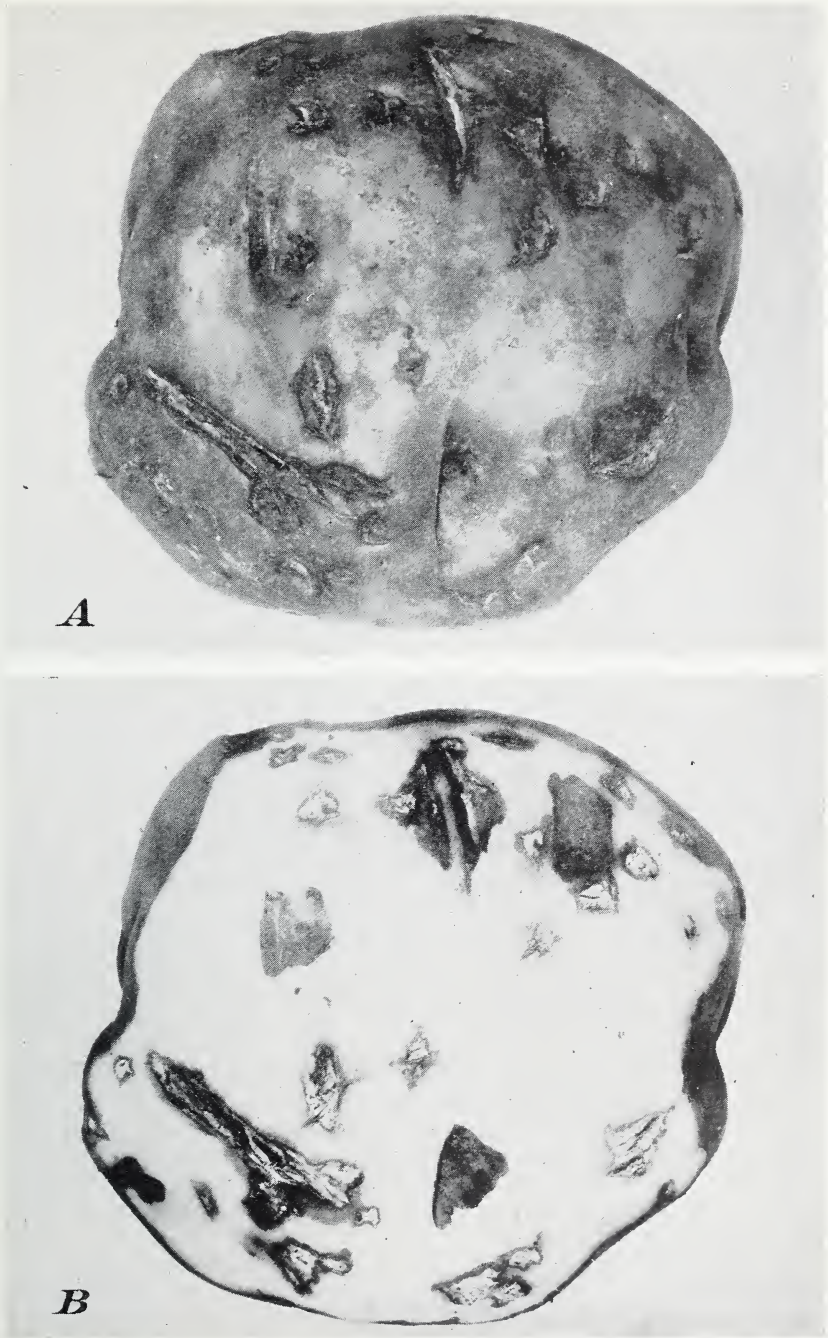

FIGURE 7.—Triumph tuber affected with bacterial soft rot in bruised and cracked areas: *A*, Unpeeled; *B*, peeled.

FIGURE 8.—Bacterial infection of lenticels on Irish Cobbler potato. Larger sunken areas show more advanced stage of decay.

The pile of rotten potatoes outside a car in which the load is being reconditioned is usually the result of bacterial soft rot (slimy soft rot), caused by a species of bacteria (*Erwinia carotovora* (Jones) Holland), accompanied by other organisms that give the rot its characteristic foul odor. Particular notice should be taken of the fact that these bacteria occur in the soil and hence are always present on potatoes as potential causes of decay whenever conditions exist that favor their growth and the infection of the tubers.

Other characteristics of the rot besides those just mentioned are loose, puffy skin; mushy, slimy flesh at rotten spots; and exuding froth caused by the development of gas. The rot frequently results from infection following heat injury in the field; it is therefore sometimes incorrectly termed "sunscald" by shippers and receivers. Strictly speaking, however, this "scald" is heat injury, which kills or injures the skin and thus opens the way for the bacteria to enter and produce the rot. Although bacterial soft rot most often results from infection of tissues that were injured by heat, it may also result from infection of cuts and bruises by soil bacteria (fig. 7). Sometimes also it results from the entrance of bacteria through enlarged lenticels (fig. 8) on potatoes dug from waterlogged soil (*7*);[11] in this case, other bacteria than those that cause typical bacterial soft rot may be found. Bacterial soft rot is also favored by keeping the potatoes closely confined in tight containers under warm, moist conditions.

Observations made on the Chicago market in the summer of 1945[12] showed bacterial soft rot following infection at lenticels in shipments of White Rose potatoes from California and of Red Warba from Nebraska. Unusually large and deeply penetrating pockets of the rot were found in many of the shipments from California. It is not known whether the infected potatoes had been injured by heat before being loaded.

Because of the importance of heat injury in predisposing potatoes to bacterial soft rot the experimental evidence of the relation of temperature and exposure to infection and decay of tubers is presented in some detail.

[11] SMITH, M. A. STUDIES OF LENTICEL INFECTION OF POTATOES BY ERWINIA CAROTOVORA AND OTHER ORGANISMS. Unpublished report. 1943.

[12] Communication from G. B. Ramsey.

FIELD AND STORAGE TESTS

Most early potatoes are harvested in weather that is moderately warm to hot. If not picked up promptly when dug they may be injured by exposure to drying winds, as already mentioned, and also by exposure to the heat of the sun. Potatoes affected by this latter injury, often referred to improperly as "scald," are very likely to decay while in transit to market, especially if they pass through warm weather (averaging above 70° F.) on the way and are not refrigerated en route.

Field observations show that during extremely hot weather heat injury may occur in potatoes either before or after they are dug. Injury before digging apparently happens after the tops have begun to die down and no longer shade the ground.[13] Wright and Peacock found the injury more severe when the soil was more or less dry than when it was moist and more severe in light sandy soil than in loam. In one locality soil temperatures during the day were reported to reach 115° F. to a depth of 3 or 4 inches. Under these conditions the potatoes did not show symptoms of injury when dug, but like those injured by heat after being dug they began to show bacterial soft rot 2 or 3 days later. Similarly on the lighter soils in the Riverhead district of Long Island, N. Y., heat injury before digging is sometimes a serious risk with Irish Cobbler potatoes, especially if the tops are killed by drought or disease so that the soil is bared in midsummer or earlier. Heat injury produced in the soil should not be confused with the greening that occurs when potatoes are exposed to even diffuse daylight. In itself the greening does not lead to decay.

In any of these cases the development and spread of bacterial soft rot depend very closely on the temperature of the potatoes between digging time and the time when they reach the market. The relation of these three factors—heat injury in the field, mechanical injuries, and temperature of the potatoes after digging—to bacterial soft rot and their importance for growers and shippers should be thoroughly understood.

When potatoes are dug in warm or hot weather two important facts about them should be kept in mind: (1) Freshly dug potatoes are very susceptible to injury by heat, although they do not always exhibit visible symptoms of the injury. The two most striking symptoms are a darkening of the exposed side of the tuber and the leakage of juice at lenticels. These may become apparent during the exposure to heat or shortly afterward, or they may not develop until after a day or two at temperatures above about 80° F. Sometimes the only evidence that injury has occurred is the eventual development of bacterial soft rot. This rot usually does not appear until a day or two after the exposure to heat. It is most likely to occur when the potatoes are kept too warm. Temperatures close to 90° are most favorable, but the rot may develop to serious proportions in unrefrigerated shipments that move to market in hot weather when the average transit temperature of the load is no higher than about 70°. The symptoms described have been

[13] R. C. Wright and W. M. Peacock. Unpublished notes concerning observations on the Eastern Shore areas of Maryland and Virginia. 1928.

seen on potatoes subjected to heat in the field and in laboratory tests. They are produced by the action of heat rays and not by the action of what should correctly be called light rays (p. 29). Under field conditions it is *sun heat*, not *sunlight*, that does the damage. (2) Potatoes lying on the soil in the sun become much warmer than the air around them, partly because the soil may be warmer than the air and partly because heat accumulates in the potatoes. Therefore potatoes may sustain heat injury in weather that is only moderately warm if they are exposed long enough. These facts were proved and their significance in the harvesting and marketing of potatoes was shown by the results of several different investigations made in various parts of the country from 1938 to 1945.

At Meridian, Miss., in June 1938,[14] injury occurred on freshly dug, immature Triumph potatoes after various exposures to the heat of the sun. Storage tests were made to determine the keeping quality of these potatoes when held at different temperatures and handled in various ways. Similar investigations were made with the Irish Cobbler variety at Arlington Experiment Farm, Rosslyn, Va., in July of the same year and at the Plant Industry Station, Beltsville, Md., in June and July 1945. For range in temperature and relative humidity during the three tests see table 3. The sky was clear most of the day at all three places.

TABLE 3.—*Range in air temperature in the shade and in relative humidity on dates tests were conducted with potatoes at Meridian, Miss., Rosslyn, Va., and Beltsville, Md.*

Place	Date	Range in air temperature in the shade	Range in relative humidity
		°F.	*Percent*
Meridian, Miss	June 6, 1938	72 (6 a. m.) to 93 (2 p. m.)	60 (8 a. m.) to 30 (4 p. m.)
Rosslyn, Va	July 9, 1938	79 (8 a. m.) to 93 (2 p. m.)	63 (8 a. m.) to 34 (4 p. m.)
Beltsville, Md	June 28, 1945	90 (10 a. m.) to 92 (3 p. m.)	82 (10 a. m.) to 65 (3 p. m.)
	July 2, 1945	85 (10 a. m.) to 93 (2:30 p. m.)	82 (10 a. m.) to 67 (3 p. m.)
	July 10, 1945	80 (10 a. m.) to 88 (3 p. m.)	80 (10 a. m.) to 72 (3 p. m.)

During the tests, records were kept of soil, air, and potato-surface temperatures. The potato temperatures recorded at Rosslyn and Beltsville can properly be called surface temperatures because they were taken electrically by means of small thermocouples thrust into the potato just under the skin. Those recorded at Meridian were taken with a mercury thermometer thrust three-fourths of an inch into the potato; they probably were somewhat lower than if they had been taken with thermocouples close to the skin.

At Meridian and Rosslyn potatoes were dug every hour or half hour during the day from early morning until late afternoon. Test lots of 100 to 200 tubers of these different diggings were picked up after having lain on the soil in the sun for ½ hour to 4 hours and were placed in storage immediately. For comparison, in each instance there was also a test lot that was picked up and stored immediately after digging. At both Meridian and Rosslyn a series of test lots dug and picked up at successive intervals during the day was held at 50°, 70°, and 90° F. and inspected after 2, 5, and 10 days. At Beltsville potatoes were dug between 9 and 10 a. m and protected from the sun until spread out on the ground. This was done at 11 a. m. on June 28.

[14] L. H. EVANS and J. M. LUTZ. Unpublished notes on the effect of heat on freshly dug, immature, and mature potatoes before and after storage, 1939.

at 10 a. m. on July 2, and at 10 a. m. and 1 p. m. on July 10. Test lots were picked up every half hour from 11 a. m. or 12 m. until 3:30 p. m., stored at 60°, 70°, and 90° and inspected after 2 days.

The results of this work at Meridian, Rosslyn, and Beltsville are in striking agreement in several important respects. This agreement is shown by the following summary in which are included a number of relevant details concerning conditions at the three places.

(1) In these three investigations none of the test potatoes while exposed on the soil in the sun showed any sign of injury except drying out, sinking, and browning at skinned places and very slight dampness at lenticels on a few tubers toward the end of the exposure period. None of them showed general darkening of the exposed side of the potato. However, this symptom as well as leakage at lenticels developed on numerous tubers after they had been held for 2 days at 90° F. The percentages of tubers found affected with bacterial soft rot during the holding tests showed that many more of them actually had been injured by heat.

It is worth repeating that to casual examination practically all of the test potatoes appeared normal when picked up except for browning at skinned places, yet a large percentage of them went down with bacterial soft rot during holding tests.

TABLE 4.—*Temperatures recorded during a test with freshly dug Irish Cobbler potatoes spread out in the sun, June 28, 1945, Beltsville, Md., and the bacterial soft rot found in tubers held for 2 days at 90° F. and 90 percent relative humidity*

Clock time	Average temperature at indicated position			Air temperature in —		Tubers affected with bacterial soft rot
	Tuber surface [1]	2 inches above tuber surface	Soil surface	Sun	Shade	
	°F.	°F.	°F.	°F.	°F.	Percent
11:00 a. m. [2]	103.4	93.6		89.5	85	
11:30 a. m.	104.3	92.5	98.8	90.7		
12 m. [3]	106.9	93.5	100.2	88.7	87	(4)
12:30 p. m.	107.7	96.3	104.0	91.7		
1:00 p. m. [2]	110.8	97.4	104.0	91.3	89	10.7
1:30 p. m.	108.9	99.0	100.4	90.7		
2:00 p. m. [3]	110.7	99.0	111.2	91.8	90	29.1
2:30 p. m. [2]	109.7	99.6	107.6	92.6		38.0
3:00 p. m. [3]	110.7	101.3	112.1	94.8	92	40.6
3:30 p. m. [3]	109.1	100.9	109.4	97.7		64.6

[1] Range 100.1° F. at 11 a. m. to 115° at 2 p. m.
[2] Time of spreading out tubers.
[3] Tubers picked up and stored.
[4] Less than 1 percent.

(2) The longer potatoes lay on the soil before being picked up the more drying out, sinking, and browning of skinned areas there was.

(3) At Meridian, potatoes of all diggings that lay on top of the soil until 3 or 4 p. m. before being picked up had surface temperatures above 110° F. if they were exposed for 2 hours or more. The highest surface temperature recorded (118°) was found in potatoes dug from 6:30 to 7 a. m. and left lying on the soil until noon or later.

(4) At Rosslyn the only lots that had surface temperatures above 110° F. were those dug at 8, 9, and 10 a. m. and not picked up until noon or later. The highest potato-surface temperature recorded (119°) was found in potatoes dug at 8 and 9 a. m. and left exposed in the field for 3½ and 4½ hours.

(5) At Beltsville the only lots that had surface temperatures above 110° F. in the field were those left on the soil until noon or later on the 2 hot days (table 4). The highest potato-surface temperature recorded in any of these tests (124°) was found in potatoes that had lain on the ground from 10 a. m. to 2 p. m. on July 2.

(6) If only the lots that were exposed in full sun during the period ending about 3:30 p. m. are considered, it is seen that the longer potatoes lay on the ground the warmer they became; that is, heat accumulated in them to such an extent that their temperature eventually greatly exceeded that of the air around them (table 4). At Beltsville there were a few temporary drops in potato tem-

FIGURE 9.—Potato tubers showing darkened rings: *A*, Exposed to heat of sun in field for 3 hours in July; *B* and *C*, exposed to radiation from infrared lamps for 3 hours, with final surface temperature of 135° F.

perature when the sky became slightly overcast but the temperature quickly rose again as soon as the sky became clear.

(7) In the storage tests bacterial soft rot was greatest at 90° F.; was very slight at 70°; and did not occur at 50° or 60° except to a very small extent in one lot at Meridian.

(8) In storage, decay was worse in potatoes that had the highest surface temperature in the field and was progressively less the lower the surface temperature of the potatoes had been in the field.

(9) Potatoes dug and spread out on the soil on a hot day, as at Meridian and Rosslyn and in the first two tests at Beltsville, decayed worse during holding than those exposed on a relatively cool day, as in the third test at Beltsville. On that day the air temperature in the shade ranged from 80° to 88° F., as compared with 90° (at 10 a. m.) to 93° (at 2 p. m.) in the other tests, and potato temperatures did not go above 105°, as compared with a maximum of 110° to 124° in the other tests.

(10) An exposure of half an hour or an hour was more dangerous for potatoes dug in the late forenoon than for those dug in the afternoon from 2 to 4 p. m.

(11) Decay occurred at cuts and bruises, at dried-out skinned places, and at leaky lenticels. The cuts and bruises were caused during digging and handling; some of them were readily noticed when the potatoes were picked up and others only by careful examination of each tuber. Their importance as places of infection emphasizes the need of care in digging early potatoes and in the subsequent handling necessary to get them to market (fig. 7).

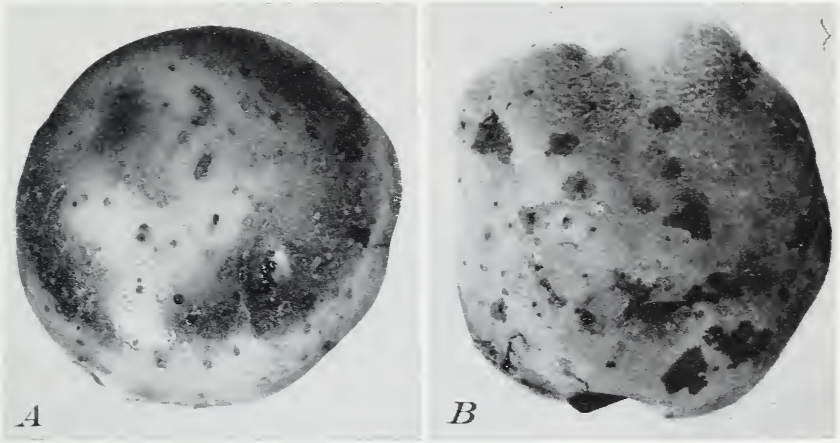

FIGURE 10.—*A*, Potato with surface temperature of 135° F. after 2 hours' exposure to radiation with infrared lamps, showing oozing of juice at lenticels; *B*, potato exposed to heat of sun in the field and then held at 90° for 48 hours, showing wet spots around lenticels.

LABORATORY TESTS WITH INFRARED LAMPS

Further proof that bacterial soft rot of potatoes results from injury by heat is furnished by the results of tests made in the laboratory with infrared lamps. Most of the rays emitted by such lamps are heat rays, and most of the heat that comes from the sun is in the infrared part of the spectrum. In repeated tests (*6*) it was found that by exposing potatoes to the rays from infrared lamps the same symptoms were produced as those previously described for potatoes left lying on the ground in the hot sun for an hour or two in the middle of the day (figs. 9 and 10).

If the potatoes were freshly dug, the only other condition necessary for heat injury to most of the potatoes tested was that the flesh just under the skin on the exposed side should reach a temperature of 110° F. or higher and remain at that temperature for 30 minutes or more. Some tubers were injured more quickly and by a lower temperature than others. In a few instances injury occurred when the surface temperature of the tuber did not go higher than about 98°. This is a fact whose significance should not be missed. It means that out of a given lot of freshly dug potatoes there may be some that will be injured by heat on a day that is not excessively hot. In the case

of the potatoes *injured at 98°* (potato-surface temperature) the air 2 inches above them was *only 88°*.

The first symptom of heat injury seen in these tests was leakage of juice at the lenticels. This usually occurred within 10 or 15 minutes after the potato flesh reached the critical temperature. Next to appear was the darkening of the exposed side of the potato, generally in the form of a bluish-black area 2 to 3 inches in diameter, but sometimes as a band or ring at the margin of the injured area.

Definite proof that heat injury predisposes potatoes to bacterial soft rot infection from soil-borne bacteria that contaminate the surface of the tubers was shown as follows. Freshly dug potatoes were sterilized externally by soaking in mercuric chloride solution for an hour and then subjected to infrared rays until the darkened ring developed and there was oozing at the lenticels. They were then held at 80° to 90° F. for a week. No rot developed (fig. 11). On the other hand, potatoes similarly treated except for not being sterilized developed typical bacterial soft rot within about 48 hours, plainly because of contamination by surface-borne bacteria (fig. 11) (*3*). This finding is significant. It should be considered in connection with another that is even more so; namely, that if potatoes are in normal, sound condition, it is very difficult to infect them with bacterial soft rot bacteria by making wounds in the flesh and putting the bacteria into them.[15]

The meaning of these facts is that when growers and shippers allow freshly dug potatoes to lie on the ground in the sun in warm or hot weather for 1 hour to 3 hours or longer or close them up tightly they are effectively preparing them for attack by a very destructive rot.

When potatoes are exposed to heat from the sun or other source, their surface temperature may become 25° to as much as 40° F. higher than that of the air round them (*6*). This means that *when the air (shade) temperature is 90°, the surface temperature of potatoes lying on the ground may reach 110° or higher, which is definitely dangerous for freshly dug potatoes.* All field observation and experimental work so far reported show that when air temperatures on a clear day reach *90° to 95°* it is *not safe* to dig potatoes unless they can be picked up and moved to shelter within 15 minutes to a half hour.

Freshly dug potatoes are susceptible to heat injury no matter what their degree of maturity (*6*), but those that are more mature usually require somewhat longer heating before injury is produced. As already shown, the one necessary and sufficient condition for most potatoes is a field temperature high enough to build up the potato-surface temperature to 110° F. or higher.

In itself heat injury has little practical significance, but in predisposing the potato to bacterial soft rot infection it is of tremendous importance. Because of this it should be fully understood in order that measures can be taken to prevent its occurrence or to minimize its effects.

VARIETAL SUSCEPTIBILITY

So far as known all varieties of potatoes are susceptible to heat injury if they are subjected to the necessary degree of heat. It has

[15] H. A. Schomer, J. S. Wiant, and L. P. McColloch. Unpublished work on the effect of heat on the susceptibility of freshly dug potatoes to bacterial soft rot. 1939.

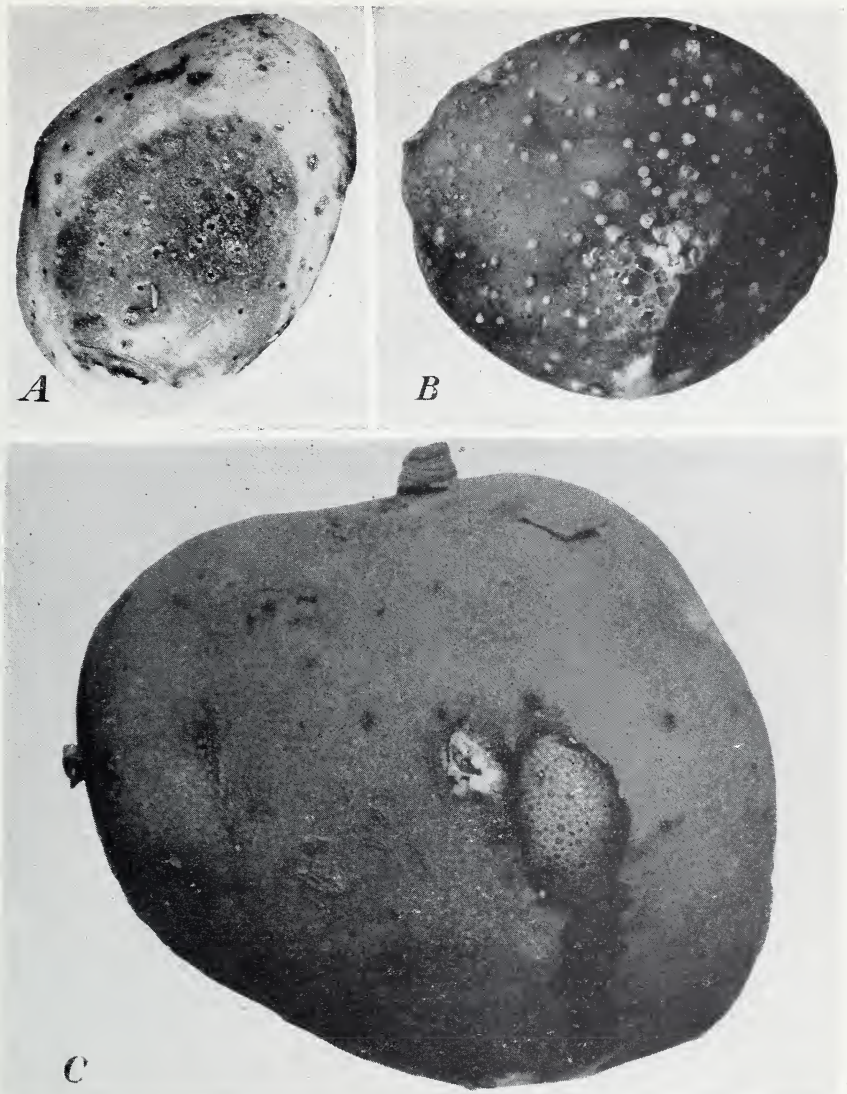

FIGURE 11.—*A*, Nonrotted, darkened, freshly dug potato sterilized by soaking in mercuric chloride solution for 1 hour, then subjected to radiation from infrared lamps for 1½ hours with final surface temperature of about 135° F., and held afterward in a moist chamber for 7 days. *B*, Freshly dug tuber not sterilized but irradiated. *C*, Freshly dug tuber injured by heat in the field (average 95°). The bacterial soft rot shown in *B* and *C* developed in 48 hours at 90°. The bubbles of gas are characteristic of this rot.

been observed, however, that when tubers of red-skinned varieties—Triumph, Red Warba, Pontiac, and Dakota Red—are subjected to air temperatures of 95° to 100° F. or higher, they become bleached in spots to a pale red or even to nearly white. Thus, on such varieties the fact that heat injury has occurred is more readily apparent than on white-skinned varieties such as Irish Cobbler or Katahdin. All of the evidence now at hand shows, however, that when exposed to

the same degree of high temperature all six of these varieties are injured to about the same extent.

Comparison of Browning and Heat Injury

Browning and heat injury of potatoes are two different phenomena each resulting from a different cause. Browning is caused by the drying out of skinned areas. It proceeds most rapidly at high temperatures but can occur at a temperature as low as 40° F. Heat injury is caused by any set of conditions that raises the surface temperature of freshly dug potatoes to 110° or higher for 30 minutes or longer. Browning is found most often on immature potatoes because they skin easily. It can develop on them to an appreciable extent within 15 minutes after the beginning of the exposure to dry air. Heat injury may occur on potatoes of any maturity if the conditions exist that have already been mentioned. It is easy to understand how both kinds of injury might occur on the same potato.

Browned areas may become sticky or slimy with bacterial growth, but the entire potato usually does not decay as is frequently the case following heat injury. If potatoes showing the surface bacterial growth at skinned spots are also attacked by bacterial soft rot, as sometimes happens, the experimental evidence now available indicates that they probably became so hot in the field that they were injured by heat as well as by drying of skinned areas.

Washing

The practice of washing potatoes before shipment has become increasingly common during recent years in many parts of the country, especially for the early crop. The chief reason for doing it is that it improves the appearance of the potatoes, especially if they are dug from wet, marly soil, and they usually bring a better price. However, for the early crop it is not always an unmixed blessing. It increases skinning and it may increase the contamination of potatoes with decay-producing organisms if the wash water is not changed frequently. On the other hand, if the washing is done only with clean running water the load of decay organisms on potatoes undoubtedly is greatly reduced.

Little work has been done to determine whether washed potatoes should be dried before shipment or may be shipped wet or at least moist. Tests with potatoes that were washed and then shipped wet and others that were washed and then dried before shipping have given contradictory results. In the work in central Nebraska (*4*) with early potatoes that were washed but not dried or dried only slightly, it was shown definitely that such potatoes can be delivered on the Chicago market in good condition if they are given adequate refrigeration in transit furnished by initial icing (or by icing several hours after loading), provided they were not subjected to adverse conditions during or after harvesting. The same has been found true for early potatoes shipped from Hastings, Fla., Kern County, Calif., and other sections. However, in Dade County, Fla., where a considerable part of the potato crop is dried with warm air after washing, it is claimed that this drying is very effective in preventing decay in transit, especially in wet seasons when late blight is prevalent.

SHIPPING PRACTICES

When placed in a truck or railroad car, early potatoes, like fruits and other vegetables, are subject to the temperature and humidity

provided by the car or truck and the weather on the way to market. Their behavior under such conditions is determined largely by the handling they receive prior to loading and the protective service under which they are shipped. Hence it is only after early potatoes leave the shipping point that the significance and importance of browning, heat injury, and mechanical injuries become evident.

Twenty years ago a large proportion of the carlot shipments made in the United States moved to market in common box cars or stock cars. At the present time most of the carlot movement is in refrigerator cars whenever they are available. The reason for the change—namely, that potatoes carry better in refrigerator cars, even though not under refrigeration, than in box cars or stock cars—is obvious now. It was not so obvious, or at least not so generally understood in 1926, when an investigation was conducted by the United States Department of Agriculture with potatoes shipped in refrigerator and box cars from the Eastern Shore of Maryland and Virginia.[16] That investigation showed that during very warm weather the temperature of potatoes was lower in refrigerator cars than in box cars and that this lower temperature was correlated with less decay. All the cars in this investigation were under "standard ventilation" (a railroad term meaning all hatches open and plugs out at temperatures above 32° F.). Another advantage shown for the refrigerator cars is that there is no chance for greening of the tubers, because the potatoes are not exposed to light as in the slatted doorway of box cars or in the still more open-slatted stock cars.

Present shipping practices for early potatoes are based partly on the experience of shippers and partly on results obtained during investigations by the United States Department of Agriculture and by various State experiment stations. The services used are essentially of three kinds, with minor variations in different parts of the country: namely, (1) standard ventilation, (2) refrigeration, and (3) precooling with vents closed to destination and without icing of cars in transit. Precooling is also used when cars are iced in transit.

Types of Load

CHOICE OF TYPE OF LOAD

Various types of load are in use for bagged early potatoes shipped in railroad cars. Some of these are desirable; others are not. In general they are designed to allow more circulation of air through the load than is provided by the so-called winter loads used for late-crop potatoes. It is possible, however, to go so far in striving for air circulation to secure desired cooling that the load is not tied together well and may undergo considerable shifting in transit. If extensive shifting occurs many of the channels through the load may become closed or blocked and actually less circulation of air through the load results than would have been possible throughout the transit period if another type of load had been used. Shifting of the load not only interferes with proper cooling in transit but also results in the cutting and bruising of potatoes, the staining of bags by juice from damaged potatoes, and the wearing of holes in the bags by their chafing against each other or the walls and floor of the car.

[16] United States Bureau of Plant Industry. comparison of common box cars and ventilated refrigerator cars in the shipment of white potatoes from the chesapeake peninsula. U. S. Bur. Plant Indus. Unnumbered Rpt. 23 pp., illus. 1926. [Processed.]

The best procedure is to use some type of stowing that ties the load together well so that it is not likely to shift much in transit but still provides channels for ample circulation of air. The best methods are the 5–3–2–3 and 5–3–2–1 pyramid loads and the pyramid through load.

The type of load used should depend upon the length of haul and the kind of protective service in transit. Heavy loads (40,000 to 45,000 pounds) of large California irrigated potatoes shipped under refrigeration to New York should be stowed in tied-in pyramid loads to eliminate wall chafing and reduce movement of floor layers. Refrigerated loads from the South to northern markets or from Colorado, Kansas, Nebraska, and other Midwestern States to midwestern markets commonly weigh 30,000 to 36,000 pounds and cool more easily than heavier loads; shifting is much less on these shorter hauls. For these, either aisle loads with one or two layers of bags capping the upright ones or pyramid loads are satisfactory. Short-haul, light loads moving without ice and depending upon ventilation for cooling, as used for some southern stock and extensively used by shippers along the mid-Atlantic seaboard, ventilate better in well-stowed aisle loads than in pyramid loads. The area from the Carolinas to the Eastern Shore of Maryland and Virginia and New Jersey can well use aisle loads for a 2- to 3-day trip with 30,000- to 36,000-pound loads.

DESCRIPTION OF LOADS

5–3–2–3 pyramid load; 360 100-pound bags.—In 5–3–2–3 pyramid loads the bottom-layer bags are stowed in an upright position 5 rows

FIGURE 12.—Part of a 5–3–2–3 pyramid load; 360 100-pound bags. Note the floor pads.

FIGURE 13.—Part of a pyramid through load; 360 100-pound bags. Note the floor pads.

wide, spaced so as to allow air lanes lengthwise through the load for air circulation and also between the load and the side walls of the car. The bags must be so spaced that the weight of the center row in the second layer rests on 3 rows in the bottom layer to avoid excessive weight on its center row. Second-layer bags are stowed flat, crosswise of the car in 3 rows, spaced to allow air lanes between rows lengthwise of the car and to tie in position the rows in the bottom layer. Third-layer bags are stowed flat, crosswise in 2 rows, spaced to allow air lanes between the rows and to tie in position the rows in the second layer. Fourth-layer bags are stowed crosswise in 3 rows of which the center one lies flat and the other 2 at an angle next to the side walls. Bags remaining after completion of the fourth layer are stowed as a partial fifth layer in 2 flat crosswise rows on each side of the doorway (fig. 12). By placing additional bags in the top layer it is possible to obtain a 40,000-pound load without changing the general arrangement of the load. When properly spaced and stowed the 5–3–2–3 pyramid load gives satisfaction. However, when the loading is carelessly done, the bags are not well alined and spaced and the ventilation of the load is reduced on that account. By leaving off the 2 slanting side bags of the top layer a 5–3–2–1 load can be obtained.

Pyramid through load; 360 100-pound bags.—In a 360-bag pyramid through load each stack contains 29 bags, 5 layers of 5 bags each stowed 1 bag lengthwise and 4 bags crosswise of the car and a sixth, or top, layer of 4 bags stowed crosswise. Five stacks are placed in each end of the car and 2 rows of 35 bags each are stowed crosswise in the doorway. All bags are laid on their sides (fig. 13).

Pyramid through load; 450 100-pound bags.—The load is started by placing 6 equally spaced upright bags at each end of the car. The remainder of the load is stowed in 10 double-stack units of 38 bags each (5 stacks in each end of the car) plus 58 bags at the doorway in a stack 2 bags wide, 7 high, and 3 to 6 long.[17] By omitting the seventh layer of bags of the 450-bag load it is possible to obtain a 40,000-pound load without changing the general loading arrangement. By omitting the seventh layer and some bags of the sixth layer, a 36,000-pound load can be obtained.

Aisle loads; 300 100-pound bags.—In aisle loads 3 rows of standing bags are first set on each half of the floor rack with the outer one leaning against the car wall. This leaves an aisle down the center. The first horizontal bags tie the standing bags together and the tops of the horizontal bags extend far enough to touch the car wall; continuation of this arrangement from each end brings the load to the doorway, where a space is left across the car between the doors. Inspection of this load is easy at the shipping point but often difficult at the terminal market, because of bags that have fallen into the aisle from the side stacks (fig. 14).

In another type of aisle load used on the eastern seaboard 7 rows of bags are set upright in each end of the car with a narrow aisle between the third and fourth rows. Over this aisle 3 layers are pyramided 1–2–2. This load usually requires a few bags between the doors to complete the minimum, 300 100-pound bags.

3 by 5 "bumped" load; 360 100-pound bags.—A "bumped" load contains 11 stacks of 15 bags each, crosswise of the car in each end and

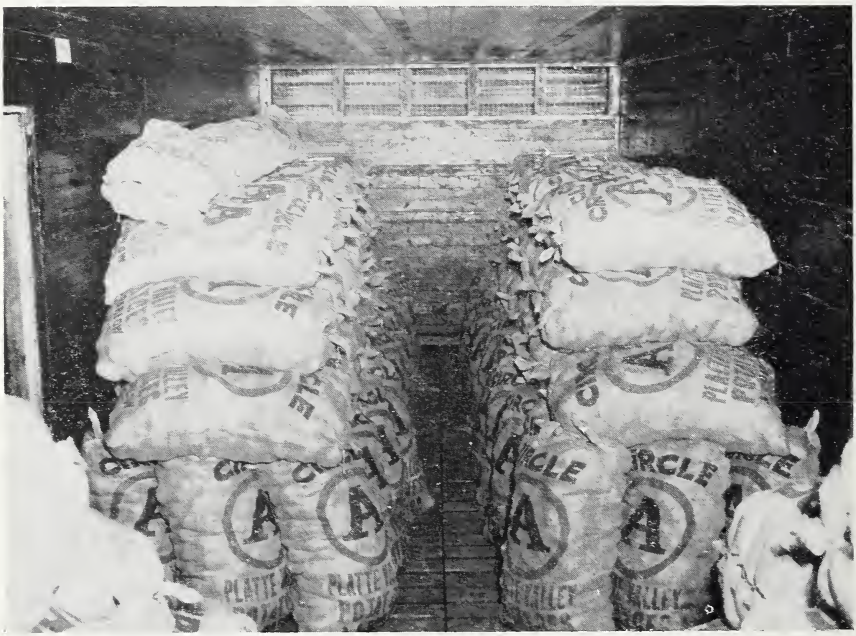

FIGURE 14.—Part of an aisle load; 300 100-pound bags.

[17] The arrangement of bags in this load, which shippers may in some cases be required to use under emergency conditions, is shown in Circular 43 of the Freight Container Bureau of the Association of American Railroads.

FIGURE 15.—Part of a 3 by 5 "bumped" load; 360 100-pound bags.

30 bags in 2 rows crosswise at the doorway. Each truckload of 5 bags is "bumped" into position from the warehouse hand truck, thus saving the labor of rehandling. The bottom bag of each truckload rests on edge on the truck and remains in that position when the truckload is bumped into position in the car. These bottom bags are subject to rocking in transit, which leads to shifting of the load (fig. 15). Edgewise bags not only rock but sometimes roll completely over, as shown by the fact that such bags may arrive with their upper sides or their edges cut by the floor racks. Floor bags from "bumped" loads on arrival at New York have shown floor-rack injury around the whole outside of the mass of potatoes in a bag.

TYPES OF PROTECTIVE SERVICE DURING SHIPMENT

STANDARD VENTILATION

If early potatoes are harvested at a time when temperatures are moderate (below 80° F.) during the day and low at night and can reach market in 2 or 3 days, they are not likely to need refrigeration in transit. This was shown by tests with potatoes shipped under standard ventilation from Dade County, Fla.,[18] in February and March. Practically no decay occurred in any of the cars, either in the commercial load or in the test packages. The weather at digging time was cool and dry, and potato temperatures did not go above 70° after 1 day in transit. During most of the trip they were well below 70°. Similar results were obtained with potatoes shipped from the Hastings district in northern Florida in late April and early May[19] and from central Nebraska in July (*4*).[20] In the last two

[18] WINSTON, J. R., and WIANT, J. S. COMPARISON OF CLOTH BAGS VS. WOODEN CRATES FOR SHIPPING DADE COUNTY (FLORIDA) POTATOES—1944. U. S. Bur. Plant Indus., Soils, and Agr. Engin. Unnumbered Rpt. 6 pp. 1944. [Processed.]

[19] See footnote 2, p. 5.

[20] See footnote 7, p. 7.

instances the weather, although not so cool as it had been earlier in Dade County, Fla., was cooler than the average for the shipping season in those districts.

In other tests in Florida it was found that when early potatoes are harvested in fairly cool weather and pass through cool or only moderately warm weather on the way to market standard ventilation is adequate.[21] Shipments made from Goulds, in southern Florida, in March carried satisfactorily to Philadelphia under standard ventilation. Similarly when test shipments were made in May from Hastings, in northern Florida, to northern markets, the results indicated that although refrigeration reduced the potato temperature in transit there was very little difference in the condition of the potatoes in the refrigerated and the nonrefrigerated loads. Decay was negligible in all of these Florida shipments.

Average transit temperatures in carloads of potatoes shipped from central Nebraska, where it is prevailingly hot and dry in July, under various protective services, including standard ventilation, are shown in figure 16.

If potatoes are exposed in the field to wind and high temperature, skinned areas on them may become browned within 15 minutes to an hour. If they are then shipped under ventilation in moderate weather their temperature will remain about as it was at loading time; in hot weather it may go higher. Under such conditions the browning that had developed prior to loading will become darker and more serious

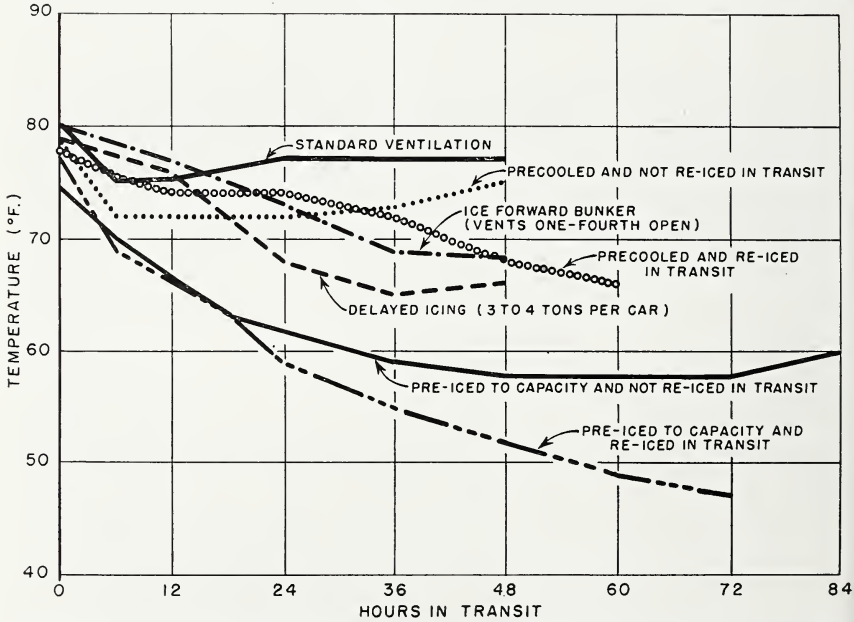

FIGURE 16.—Average temperature of potatoes in bags at three positions in cars shipped by different methods from central Nebraska in warm weather. (Courtesy of the Nebraska Agricultural Experiment Station.)

[21] WINSTON, J. R. INVESTIGATIONS ON THE PRECOOLING AND TRANSPORTATION OF FLORIDA POTATOES, 1941. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Div. Fruit and Veg. Crops and Dis. H. T. & S. Office Rpt. 81, 15 pp., illus. 1942. [Processed.]

in transit and the browned areas are likely to show stickiness, shallow bacterial decay, and eventually bacterial soft rot. It was concluded from the results of the Nebraska tests (*4*) that it is very hazardous to ship washed, early potatoes under standard ventilation from that region unless the maximum daily temperature at digging time is below 80° F.

An illustration of what happens to potatoes in transit without refrigeration, when they have been exposed to sun and wind in the field, is furnished by the results of a test made with California potatoes early in June 1938.[22] Test lots were exposed to sun or wind for various lengths of time after digging. They were then shipped to Chicago by express without refrigeration. Their condition when inspected at Chicago a week after digging is shown in table 5.

TABLE 5.—*Effect of sunlight and wind in the field at Shafter, Calif., on June 3, 1938, on tubers of the White Rose variety shipped by express to Chicago, Ill.*

Treatment	Tubers showing —		
	Browning	Dried-out, sunken spots	Decay
	Percent	*Percent*	*Percent*
Exposure to sunlight:			
60 minutes	48	37	4
45 minutes	38	17	3
30 minutes	33	7	0
15 minutes	23	0	0
No exposure to sunlight	11	0	0
Shading and exposure to wind:			
30 minutes	88	0	8
15 minutes	79	0	0

Although this test was not made under commercial conditions, the facts it established are significant. It is evident from table 5 that the longer the exposure in the field the greater was the injury. The highest percentage of browning occurred on potatoes that had been exposed to wind for half an hour, but kept shaded—that is, without any possibility of action by direct sunlight.

The effects of injury by heat and wind at the shipping point may not end with the transit period. After potatoes arrive at the market there is often a period of a week or more before they reach the consumer. Regardless of how they had been shipped, if they are held at ordinary summer temperatures in a receiver's warehouse or in a retail store, browning will become more pronounced and stickiness and decay may develop to a serious extent on the browned spots. This is shown in table 6, which gives the results of a test with Nebraska potatoes shipped to Chicago in July 1942 (*4*). Similar results were obtained in a test with Florida potatoes in 1943.[23]

The increase in decay and browning after holding 1 week at 78° to 83° F. was enough to damage the appearance of the potatoes and greatly reduce their sales value. The important fact is that the increase occurred even on potatoes from the car that was pre-iced and re-iced in transit. As is well said in Nebraska Experiment Station

[22] BARGER, W. R., PENTZER, W. T., RAMSEY, G. B., and others. REPORT ON SHIPPING TESTS WITH EARLY POTATOES FROM KERN COUNTY, CALIFORNIA, 1938. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Div. Fruit and Veg. Crops and Dis. H. T. & S. Office Rpt. 27, 16 pp., illus. 1938. [Processed.]

[23] See footnote 2, p. 5.

Bulletin 364 (*4, p. 13*): "Damage done before potatoes are loaded cannot be undone by any methods of shipping." Observations made during the transportation work with early potatoes show that browning is often more pronounced in cars under ventilation than in those having the ventilating devices closed. The difference is undoubtedly due chiefly to the circulation of air through the load in a ventilated car, the situation being similar to that existing when potatoes were freely exposed to the wind after being dug (p. 29) or were placed experimentally in the blast from an electric fan (p. 9). Probably one of the reasons for less browning in iced than in ventilated cars is the absence of air movement in the former. Higher humidity in the iced cars also tends to reduce browning.

TABLE 6.—*Condition of potatoes in test shipment of Triumph potatoes from central Nebraska upon arrival at Chicago, Ill., on July 18, 1942, and after holding 1 week*

Shipping service	Date inspected	Tubers in indicated part of car showing—					
		Browning			Decay		
		Bottom bunker	Middle layer (quarter length)	Top layer (doorway)	Bottom bunker	Middle layer (quarter length)	Top layer (doorway)
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Precooling	July 18	11	11	18	13	14	19
	July 25	13	19	17	24	19	35
Pre-icing and re-icing	July 18	4	5	9	5	7	10
	July 25	11	10	9	25	23	11

INITIAL ICING ONLY

Investigations by the United States Department of Agriculture and cooperating agencies during the period from 1939 to 1944, inclusive, have shown that, except for early shipments from the South during comparatively cool weather, the transportation of early potatoes under some form of refrigeration gives better results than shipment under ventilation. Tests with shipments from central Nebraska to Chicago during warm, summer weather (*4*) showed that either precooled shipments or those iced 24 to 36 hours after loading developed less decay during transportation and subsequent storage than those shipped under standard ventilation. The ventilated shipments usually presented a poorer appearance on arrival at destination because of excessive browning and withering.

In 1938, 1939, and 1941, 17 test carloads of early potatoes were shipped from Shafter, Calif., and nearby points under initial icing only (*1*). A few of these went to New York, N. Y., and Detroit, Mich., but most of them went to Chicago, Ill. In these shipments, en route 6 to 10 days during hot weather, one icing within 48 hours after loading reduced browning in transit but best results came from hydrocooling (cooling in ice water) followed by initial icing. Test lots that were mature when loaded arrived in better condition than those that were immature. Severely skinned lots, either mature or immature, were more damaged by browning, stickiness, and decay on arrival at destination than those that were only slightly skinned. In

this California work, as in that in Nebraska, shipments under refrigeration arrived in better condition than those under standard ventilation, even though some of the latter were hydrocooled before loading.

The results of these tests, considered as a whole, reemphasize the point made in connection with the Nebraska work, that no method of handling early potatoes in transit can entirely overcome the bad effects of improper handling at the shipping point.

INITIAL ICING WITH ONE RE-ICING IN TRANSIT

Test cars of early potatoes were shipped from central Nebraska to Chicago, Ill., in July under initial icing followed by one re-icing in transit. The temperature of the load dropped steadily throughout the trip, reaching an average of 46° F. on arrival at Chicago, which is lower than necessary for good delivery of potatoes at market (fig. 16). Ramsey and his associates (*4*, *pp. 22*, *23*) noted:

> The potatoes carried well and showed little discoloration or decay, but this low temperature at unloading time caused condensation of an excessive amount of moisture on the tubers. A slight amount is not injurious but when the potatoes become wet enough to remain damp for several hours after unloading the development of decay is somewhat favored and their keeping quality is impaired.

PRE-ICING

In tests with cars that were pre-iced to capacity before loading in Nebraska and not re-iced in transit, Ramsey and his associates (*4*) found that the loads arrived at Chicago in good condition and had a temperature of 57° F. on arrival, which is low enough to give effective control of decay. These authors (*4*, *p. 23*) concluded from tests including both pre-icing and re-icing:

> Judging from the results of the tests it appears that where cars are going no farther than Chicago the cost of re-icing may well be saved in cars that have been pre-iced to capacity the night before loading.

Undoubtedly this is equally true for shipments of early potatoes from other parts of the country where the time in transit is not more than about 3 days. Under emergency conditions this is fortunate because the experience of shippers during the last 2 years has shown that it is occasionally difficult or impossible to obtain ice for re-icing and sometimes for even an initial icing of potato shipments.

DELAYED ICING

In Nebraska (*4*) tests were conducted on the effect of delayed icing, that is, sending loaded cars out with bunkers dry and icing them at the first icing station en route. It was found that this method gave good control of browning and decay, provided the average temperatures of the potatoes when loaded were between 60° and 70° F. However, when the potatoes averaged 75° to 80° at loading time, delayed icing did not give as good results as pre-icing the cars to capacity before they were loaded.

STAGE ICING

Tests with early potatoes from central Nebraska in August (*4*) and from the Hastings, Fla., district [24] in May showed that loads in cars

[24] See footnote 2, p. 5.

under upper-half-stage (upper-half-bunker) icing arrived at market in as good condition as those with bunkers fully iced initially but not re-iced and in better condition than those shipped under standard ventilation or with ice in the lower half of the bunker. Lower-half-bunker icing is by no means the same as upper-half-stage icing and is far less effective because it does not give as good circulation of cold air over and through the load (*2*).

The results with upper-half-stage icing are worth the careful consideration of shippers who may be faced with a shortage of ice at a time when it is of the utmost importance that their shipments be refrigerated. Under such conditions they might well ask themselves this question: If ice in only the upper half of the bunkers will give the necessary cooling, why fill the bunkers full? If enough ice is used to fill the bunkers only half full, it is much better to put it in the upper half where it will do the most good.

FAN CARS

There are now available to shippers a limited number of cars equipped with fans designed to speed up the circulation of air around and through the load and so hasten cooling. These fans or fan systems are of various types. In the commonest type the fans are in reality two sets of seven centrifugal blowers, one set mounted on a shaft at each end of the car, underneath the floor racks and so arranged that regardless of the direction the car is moved air is forced up through the ice bunkers and out over the top of the load (fig. 17).

The shafts and consequently the blowers or fans are operated by a friction drive on a car wheel at each end of the car. Cars equipped with this type of fan and pre-iced were used in tests with shipments of early potatoes from central Nebraska in August (*4*). The results obtained showed that by use of the fans while the car was in motion the difference between the temperatures of top and bottom potatoes was only 3° to 6° F., whereas in a standard car it was 10° to 20°. Such an equalization of temperature is highly desirable because it keeps the upper part of the load from becoming so warm as to favor decay and at the same time avoids cooling the bottom of the load more than is necessary.

PRECOOLING

In commercial operations carloads of potatoes are precooled (1) with mechanical, or truck-unit, precoolers, (2) with portable fans mounted at the upper-bunker opening at each end of the car, or (3) by operating the built-in fans in fan cars by means of motors before the cars are shipped. The effect of these different methods has been investigated in connection with experimental shipments of carload lots of potatoes from central Nebraska in July and August (*4*) (fig. 16) and from northern Florida in May.[25]

The first of these methods cools the load, especially the upper part, by means of cold air blown into the car at the top doorway from a mechanical refrigerating unit outside the car. The air absorbs heat from the potatoes as it is forced over and through the load and

[25] See footnote 2, p. 5.

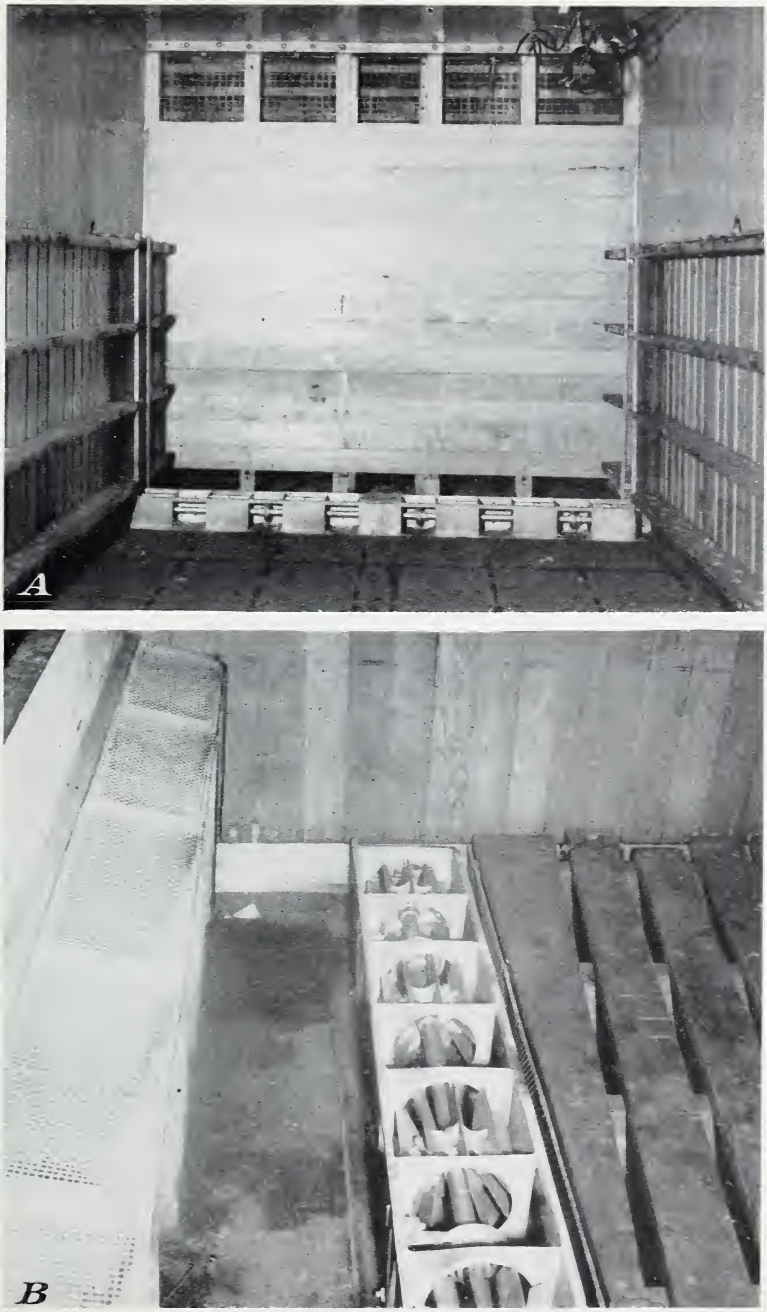

FIGURE 17.—*A*, Refrigerator car with floor racks lifted showing Preco fan system. There are seven fans on a common shaft covered with a housing to direct air back to bunkers. *B*, Detail of Preco fan system. The screen installation at the extreme left is turned down into space at left of fans before loading begins.

is returned to the cooling unit through the bottom part of the doorway. The other two methods cool the load by circulating air that has been cooled by the ice in the bunkers. The air current is moved upward through the ice mass in the bunkers, out through the top bunker openings, then over and down through the load, then under the floor racks, and back to the ice again.

All three methods are very effective in cooling the load if the precooling lasts for 5 to 6 hours or more. However, under commercial conditions it often lasts for only 2 or 3 hours, with the result that only the upper part of the load is brought even approximately close to a desirable temperature before the precooling is stopped. Differences will be found depending on the kind of packages used. Potatoes cool faster in crates and tubs than in bags. It cannot be too strongly emphasized that thorough precooling cannot be done in a hurry. Merely "exposing" a carload of potatoes to the action of a precooling apparatus, whether bunker fans, mechanical truck unit, or the permanently installed fans in a fan car, for only an hour or two is not enough. If the shipper is relying on precooling to protect his load without use of ice while in transit he should insist that the potato temperature be brought to some definite figure before precooling stops. Evidence obtained in tests conducted in Nebraska (*4, p. 19*) showed that "cars of potatoes with empty bunkers precooled long enough to reduce the average temperature of the load to about 60° F. should carry satisfactorily for short transit periods"; that is, without serious development of decay and browning.

If the bunkers contain only a little ice at the end of precooling and the car is not re-iced, the load is cooled no further during the transit period and its temperature may even rise to an average close to that generally registered in ventilated shipments. This is particularly true of cars loaded and shipped in hot weather, as, for example, from central Nebraska in July and August (*4*).

Another point needs emphasizing here. The average temperature of the load cannot be determined by inserting a thermometer in one potato in a bag at the doorway. Temperatures should always be taken at several places in the load, preferably at the top and bottom doorway, top quarter length, and top bunker and if possible at the bottom quarter length.

For long hauls in hot weather precooling alone is not sufficient. It should be supplemented by transit refrigeration. Tests made with potatoes from Kern County, Calif., showed that of two lots cooled to about 50° F. in an ice-water shower, the one which was shipped under ventilation arrived in New York with skinned areas sticky, whereas the one that was initially iced after loading arrived in firm, white condition. In neither shipment were the potatoes dried after being washed. From the Nebraska work (*4, p. 19*) it was concluded that "shipments depending upon precooling alone for refrigeration are not recommended for distant markets during hot weather or if conditions are such as to make it probable that the cars may remain on track for several days before being unloaded."

In California the air blast incident to car precooling has increased browning over that observed in cars not precooled, especially in the top layers of the load, and generally hydrocooling has proved to be preferable to a cold air blast for precooling.

Choice of Type of Service

It is evident from the foregoing discussion that no one type of service can be recommended for the transportation of early potatoes from all parts of the country. The type needed for good delivery to market will depend very largely on local conditions, particularly the weather at digging time and that through which the shipment is likely to pass while en route to destination.

In southern Florida early potatoes are harvested from December to May, usually in relatively cool weather, and move to market through weather that grows increasingly cooler the farther north they go. As a rule, therefore, they can be shipped satisfactorily under standard ventilation except during periods of unseasonably warm weather. Even then initial icing only will usually be sufficient, since the vents can be opened as the car moves into colder territory northward.

The same methods are usually satisfactory for northern Florida, southern Alabama, Mississippi, Georgia, Louisiana, and southern Texas, where potatoes are dug and shipped in weather not much warmer than that in southern Florida, except possibly toward the end of the season. At that time or if the transit period is longer than 2 or 3 days an initial icing may be desirable.

Along the Atlantic seaboard from the Carolinas northward the weather at potato-digging time is much warmer than in the earlier districts. This brings a correspondingly greater hazard in getting shipments to distant markets, particularly because the weather through which they must pass en route to market is likewise very warm at this time. Consequently, initial icing is usually a necessity if the potatoes are to arrive without undue browning and decay. For short hauls to nearby markets shipment under ventilation can be used safely if the potatoes have been picked up and hauled from the field soon after being dug.

Shipments of early potatoes from the central midwestern region are usually made during very warm weather, both in the producing area and all the way to market. They are practically certain to need good refrigeration in transit. If the transit period is to be longer than 2 or 3 days, initial icing plus re-icing in transit will usually be desirable. Precooling to an average load temperature of 60° F. followed by re-icing in transit has given good results but is relatively expensive.

Shipments from California are also generally made during hot weather, which is in addition very dry in the producing district and during the first part of the trip. Those moving to markets east of the Rocky Mountains should be under initial icing plus at least one re-icing in transit. Toward the end of the season two re-icings or even standard refrigeration may be necessary. California shipments moving to points west of the Rockies should not require more than an initial icing.

Kinds of Shipping Containers

Beginning in 1942 and continuing through 1943 there was a shortage of burlap bags. Consequently, potato shippers were compelled to use substitute containers of various kinds, among which were bags

made of paper or various cotton materials and wooden baskets and crates. Some of these proved satisfactory; others did not. White cotton bags were much less attractive at destination than tan ones, because of spotting. Coarse-mesh bags caused bag marks on the potatoes and were hard on workmen's hands. Later burlap became available and wood containers scarce and expensive. This was a special problem in Florida, where shippers had used wood containers for a long time and preferred them to bags. Observations on experimental and commercial shipments of potatoes from California, Colorado, and Florida in the various kinds of containers that were available have led to the following conclusions:

In California shipments [26] coarse-mesh bags increased shrinkage and bag marking in transit. Victory-cloth bags proved very desirable and, although they were not quite so strong as burlap ones and the potatoes in them were more subject to greening than those in burlap, undoubtedly these objections could be met by proper handling during loading and at the market.

White cotton bags were less desirable, because they were usually not so strong and because bag spotting due to placing wet potatoes in them or from their contact with dirty floors and car walls caused some confusion on the market, where spotting of burlap bags has usually been associated with decay. Subsequent experience showed that the trade has learned to differentiate between spots resulting from wetness and those resulting from decay.

The relatively high humidity that occurred in paper bags as compared with that in burlap not only reduced shrinkage and browning in transit but also promoted the development of new skin over skinned areas. However, this high humidity also increased decay, particularly of skinned potatoes if they had been exposed to heat and dry wind in the field after digging and during hauling to the packing house and of potatoes that were held at temperatures above 70° F. Heavy decay was observed in experimental lots of potatoes shipped from Florida to New York in paper bags with specially treated liners that made them more retentive of moisture than the usual type.

Paper bags, mostly of the 50-pound size, have proved generally satisfactory and popular, but those of the 100-pound size have not, because of the objectionable number of bag failures, which necessitate rebagging at the market.

In Colorado shipments (*4*) six types of cloth bags were tested. Burlap bags proved best, followed in order by bags of Victory cloth, Osnaburg, cotton sheeting, waterproofed cotton sheeting, and coarse-mesh cotton bags. Losses in weight in transit were greatest with coarse-mesh bags and least with bags of cotton sheeting, but the differences were not great.

In Florida shipments [27] burlap and cotton bags seemed to be as satisfactory as the wood containers that had been used customarily for the shipment of new potatoes. No significant difference was noted between potatoes in the different kinds of containers that would make one more satisfactory than another, but shippers not equipped to

[26] Barger, W. R., Morris, L. L., and Ramsey, G. B. paper and cotton shipping bags for kern county potatoes. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Div. Fruit and Veg. Crops and Dis. Unnumbered Rpt. 5 pp. 1943. [Processed.]

[27] See footnote 18, p. 27.

dry potatoes after they are washed probably will continue to favor wood containers.

In other Florida tests [28] differences in loss in weight of potatoes in three kinds of bags (cotton mesh, cotton sheeting, and burlap) were not great, but slightly greater loss occurred in those in cotton mesh bags.

BRUISING

Bruising and other mechanical injuries are often caused by rough handling, much of which unfortunately cannot be avoided except at prohibitive cost. Rough handling may occur during harvest, hauling from the field, washing, grading, and placing in containers for shipment. If potatoes are in bags, they may be loaded onto trucks or into railroad cars so carelessly as to cause excessive cracking. Trucks with padded floors help in preventing injury, and care in setting the bags in place is also helpful. It is decidedly bad practice to *throw* a bag or any other container into place or to set it down hard on end to make a tight fit in the load. Walking over the load is also bad practice (fig. 18). If it cannot be avoided entirely, it should always be kept to a minimum and a plank or board used for the loaders to walk on. Examination of the contents of the containers, especially bags, that have been handled roughly usually shows serious cracking and bruising of the tubers.

Injuries open the way for decay in transit if temperature and humidity are favorable. They also damage the appearance of the

FIGURE 18.—Loading bagged potatoes in the field. Note that the men on the truck are standing on the bed of the truck, not on the bags of potatoes. On a hot or dry and windy day the load should be covered with a tarpaulin as shown in figure 5.

[28] See footnote 2, p. 5.

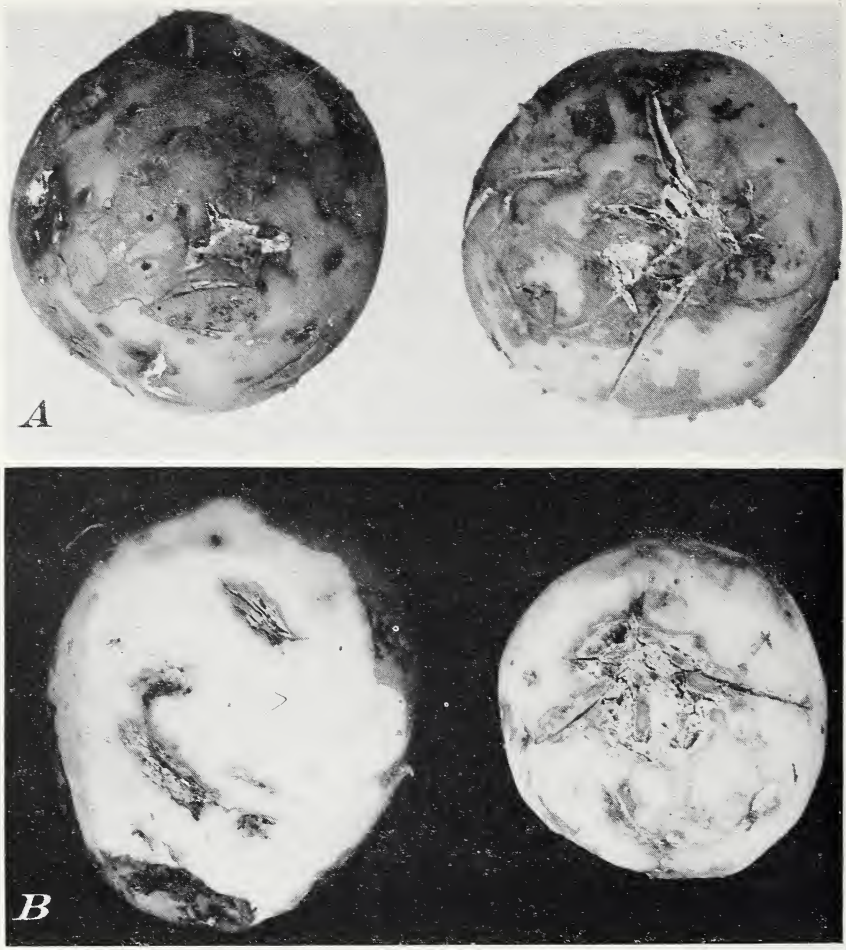

FIGURE 19.—*A*, Unpeeled potatoes showing cuts and bruises caused by rough handling; *B*, peeled potatoes showing cuts and shatter bruises.

shipment, lower its market value, and lead to waste when the potatoes are prepared for the table.

The experience of peeling potatoes from commercial shipments now and then would give many a grower, field hand, or car or truck loader a new idea of how much loss is caused by the treatment potatoes undergo before they reach the consumer. The extent of the damage that may be caused by rough handling is shown in figures 7 and 19.

It is true, of course, that the price which potatoes usually bring does not justify handling them with the care ordinarily used in packing and marketing such products as apples and pears. There can be no doubt, however, that much of the mechanical injury done to potatoes during harvesting and marketing could be prevented by fully justifiable attention to handling methods.

A type of injury frequently occurring on potatoes and one that has received increased attention during the last 2 or 3 years, when heavier loading has been required, is that caused in carlot shipments

by the pressure of the load on the lower layers, particularly the lower side of the bags in the bottom layer. During the time when the Office of Defense Transportation increased the minimum potato load requirement from 30,000 to 36,000 pounds or even 45,000 pounds, shippers and receivers were inclined to blame all of the so-called floor bruising on the use of the heavier load, although more or less damage of this kind always prevailed even in the lighter loads. In considering the damage sustained in this connection it should be noted that in the wholesale trade the bag is the unit; therefore, damage done to the potatoes on only one side of a bag affects the market value of the whole bag and the number of bags that are thus affected similarly influences the return on the whole carload when it is sold as a unit. This effect is often out of all proportion to the number of potatoes that show injury and is especially important if the crushing or bruising releases juice that causes dirty or wet spots on the bags or if holes are worn in the bags by rubbing against the walls or floor rack of the car while in transit.

Bruising from whatever cause is sometimes so serious a problem to receivers and distributors of potatoes in large terminal markets that they find it necessary to recondition the shipments which they handle. In doing this the receiver discards badly bruised tubers and resacks them in clean bags. Bruised potatoes which are still fit for food are graded out of a No. 1 pack and are either trimmed or sold at a discount.

Tests were conducted in 1943 and 1944, using shipments of Triumph and White Rose potatoes from Kern County, Calif.,[29] to determine the effectiveness of various kinds of padding material in preventing bruising, especially of the under side of bags resting on the floor racks. In these tests two kinds of floor pads were used; excelsior pads consisting of matted excelsior in a paper sleeve and paper pads consisting of two layers of paper glued together at the edges and filled with shredded paper. These pads were about ½ inch thick, 12 inches wide, and 30 inches long; this is long enough to accommodate one bag laid flat or two standing upright. When placed in the car they were spaced so as to leave the floor rack uncovered between the rows of the load and not to interfere with air circulation. Pads were used under part of each load, leaving the rest of the load for comparison. Observations were also made on the commercial use by shippers of excelsior, straw, and shredded paper spread on the floor underneath the bottom layer of bags.

Results of tests with these two types of pads were in brief as follows: With 3 by 5 "bumped" loads excessive bruising, affecting nearly 10 percent of the potatoes in one test, occurred in bottom-layer bags on bare floor racks (fig. 20), whereas very little bruising occurred in the portion of the load where floor pads were used. In unprotected portions of pyramid through loads bruising amounted to less than 1 percent, thus indicating that excessive bruising can be prevented by careful handling of bags and proper loading methods. Aisle-type loads without floor pads carried better than "bumped" loads but not as well as pyramid through loads. The probable reason for the dif-

[29] Barger, W. R., Shear, E. V., and Morris, L. L. the prevention of mechanical injury during transit of new-crop potatoes. Calif. Agr. Expt. Sta. Unnumbered Rpt. 7 pp. illus. 1945. [Processed.]

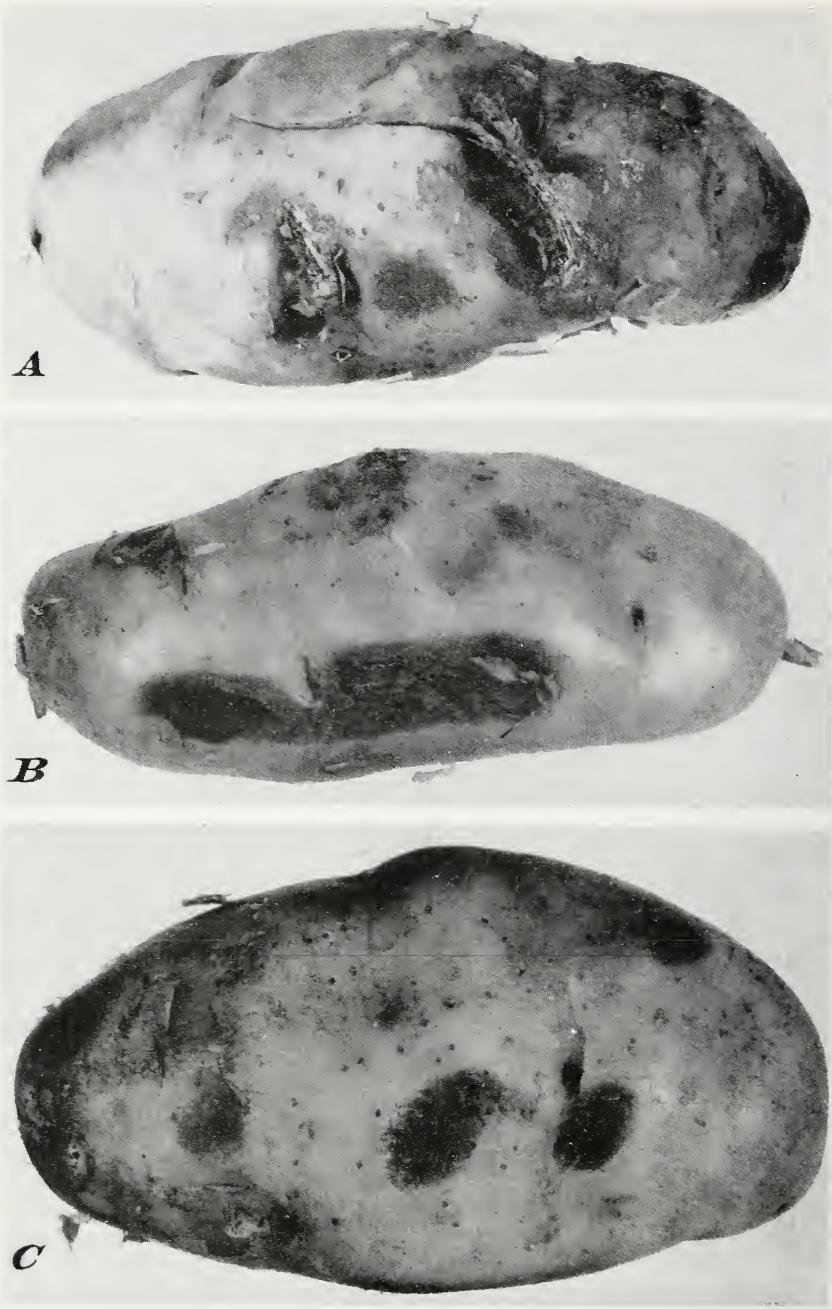

FIGURE 20.—*A*, Potato from upper-layer bag of a carload of White Rose potatoes shipped from California to New York. Crusted starch on surface of cut area suggests that the injuries probably occurred prior to the transit period. *B* and *C*, Potatoes from lower-layer bags from unpadded end of the same carload, showing floor bruising.

ferences is that shifting in transit is less extensive in the aisle-type load than in the "bumped" load but more extensive than in the pyramid through load. In all types of loads bruising and bag spotting were reduced by the use of floor pads, which also greatly reduced the number of holes in bottom-layer bags.

Records obtained on the transit temperature of potatoes in bags in the middle of the load and on the temperature and condition of the loads on arrival at destination did not indicate that there was any heating or that the air circulation through the load was inadequate when floor pads were used.

"Feathering" in bottom-layer bags was usually worse in those resting on the bare floor than in those on pads. The difference was most marked when the potatoes were relatively immature.

Inspection of shipments at destination [30] throughout the Kern County shipping season showed a decided decrease in decay and bruising as the potatoes became more mature and thereby less susceptible to injury.

From inspections of about 30 test carloads of new potatoes it seems very probable that much of the bruising and other injury found could not be attributed to the heavy loading requirement then in effect but that they could readily have been prevented by using a better loading plan, by more careful stowage of the load, and by using pads on the floor racks.

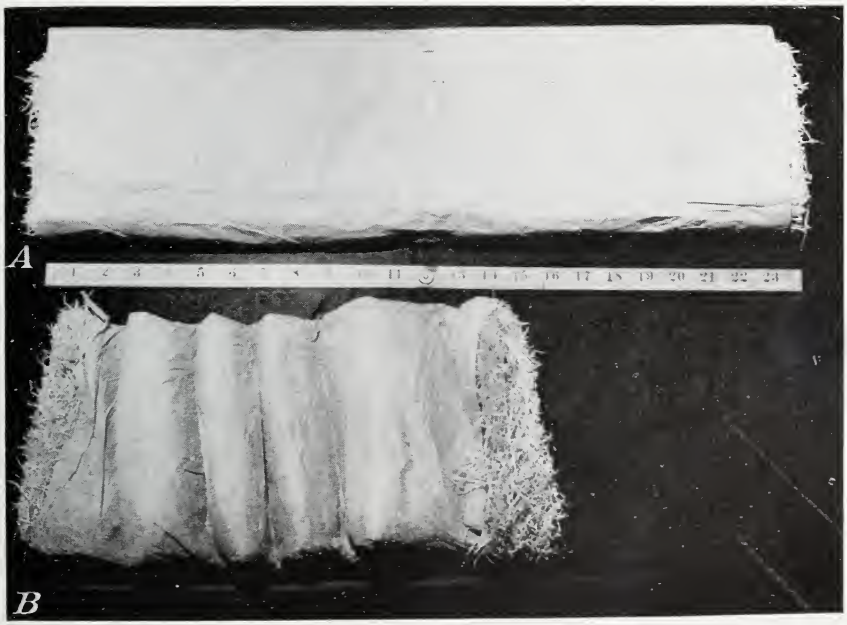

FIGURE 21.—*A*, A 24-inch paper-covered excelsior car pad before being used. *B*, Car pad crumpled, or "pleated," by the shifting back and forth of the lower layer of the load in transit from California to New York. The pad had been placed lengthwise of the car.

[30] W. R. BARGER, L. L. MORRIS, E. V. SHEAR, and J. S. WIANT. Unpublished report on shipping tests with early potatoes from Kern County, Calif., and destination inspection of test cars, 1943 and 1944.

It is probably better to lay pads crosswise of the car rather than lengthwise, because in the latter position they are likely to become wrinkled or "pleated" (fig. 21) by the endwise shifting back and forth of the bottom layer of the load. When in this condition they are, of course, greatly shortened so that they do not afford the protection from bruising that they should. Evidence obtained on the New York market showed clearly that in 36,000-pound loads the potatoes were injured in the lower layers of bags only where the bags had slid or rolled back and forth on the floor racks, as shown by the wrinkling of floor pads and by bruised tubers in the lowermost part of the bags.

When box cars are used, as was formerly customary in some parts of the East, floor bruising may sometimes be confused with an injury caused by salt, fertilizers, or other soluble chemicals on the car floor or walls. The two can usually be distinguished by the fact (*9*) that the potato flesh underneath an area that has been injured by some chemical usually is soft and rubbery to a depth of an eighth to a half inch and the skin is usually wrinkled. In contrast, ordinary floor bruising is usually characterized by hard, dry areas, flattened and with an incrustation of starch. Although chemical injury occurs only at bruises, such bruises are only at places where potatoes are in contact with a chemical *under pressure*. Adjacent tissue always becomes soft and flabby.

LOSS OF WEIGHT IN TRANSIT

Data on the loss of weight of early potatoes in commercial carlot shipments from the South, the Middle West, and the Far West to northern and eastern markets are found in table 7. The information in this table gives some idea of the shrinkage that may be expected in early potatoes during transit. It should be useful to government agencies, shippers, transportation companies, and receivers, in connection with regulations promulgated by the Office of Price Administration and in settling controversies arising out of the enforcement of the Perishable Agricultural Commodities Act. In these 33 test shipments the loss of weight ranged from 0.1 percent to 2.5 percent and averaged 1.3 percent. The shrinkage was greater in severely skinned potatoes than in those only slightly skinned. There was no great difference attributable to the kind of container used. Based on the results of these tests it appears that ordinarily, and in the absence of decay, claims for shrinkage in transit in excess of about 2.5 percent cannot be supported. After removal of potatoes from the confined atmosphere of a refrigerator car loss of weight may proceed much more rapidly.

TABLE 7.—*Loss of weight of early potatoes during transit in commercial shipments*

State of origin	Destination	Date	Period from loading to unloading (days)	Treatment before loading	Kind of container	Service in transit	Cars (number)	Loss of weight (percent)
		1943						
Alabama	New York, N. Y.	May-June	7	No washing	Burlap bags	Pre-icing	1	0.8
	do	do	7	Washing and shipping wet	do	do	1	.5
	do	do	7	Washing and shipping dry	do	do	1	1.5
	Chicago, Ill.	do	5	No washing	do	Standard ventilation	1	1.3
	do	do	5	Washing and shipping wet	do	do	1	1.1
	do	do	5	Washing and shipping dry	do	do	1	2.1
		1938						
California	New York, N. Y.	June	9	Washing and shipping wet	do	Initial icing	1	[1] 1.0
	do	do	9	do	do	do	1	[2] 1.7
	do	do	9	do	do	do	1	[3] 2.5
		1944						
Colorado	Chicago, Ill.	Aug.	3	do	Cotton mesh bags	Icing at North Platte, Nebr.	1	1.0
	do	do	3	do	Victory-cloth bags	do		.7
	do	do	3	do	Osnaburg bags	do		.4
	do	do	3	do	Cotton-sheeting bags	do		.1
	do	do	3	do	Burlap bags	do		.6
	do	do	3	do	Waterproof-sheeting bags	do		.2
Florida	Philadelphia, Pa.	Feb.-Mar.	5	do	Cotton and burlap bags	Standard ventilation	1	1.1
	do	do	5	do	Crates	do		[4] 2.3
	do	do	4	do	Cotton and burlap bags	do	1	.6
	do	do	4	do	Crates	do		1.1
	New York, N. Y.	Mar.	5	do	Cotton and burlap bags	do	1	1.1
	do	do	5	do	Crates	do		1.1
	Baltimore, Md.	Mar.	7	do	Cotton and burlap bags	do	1	.9
	do	do	7	do	Crates	do		1.0
	do	do	5	do	Cotton and burlap bags	do	1	.8
	do	do	5	do	Crates	do		1.1
		1942						
Nebraska	Chicago, Ill.	Aug.	3	do	Burlap bags	Precooling	4	1.2
	do	do	3	do	do	Precing	9	1.5
	do	do	3	do	do	Icing in transit	5	1.0
Total or average							33	1.3

[1] U. S. No. 1 tubers.
[2] Tubers slightly skinned.
[3] Tubers severely skinned.
[4] Difference may have resulted in part from loss of small potatoes between slats.

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